

**PHYSICAL WORKLOAD AND LABOUR
PRODUCTIVITY IN TIMBER HARVESTING
IN PAKISTAN**

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IN PAKISTAN

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PREFACE

The study is a part of the activities of a cooperation project between the Federal Republic of Germany through the GTZ (German Agency for Technical Cooperation) and the Islamic Republic of Pakistan, for the promotion of research and teaching facilities in Forest Engineering and Forest Products Engineering at the Pakistan Forest Institute Peshawar, Pakistan. This Pak-German Cooperation Project was started in 1981 and will remain continued upto 1990.

The entire study covered a period of almost three years from May, 1983 to April, 1986. Nearly a time of 8 months from August, 1984 to March, 1985 was devoted to the organization of field studies and collection of data in Pakistan. Data analysis and write-up of the work was completed at the Institute of Work Science and Operational Methods in Forestry, Faculty of Forestry, University of Munich, Federal Republic of Germany under the guidance of Professor Dr. H. Löffler.

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1. INTRODUCTION

1.1 THE BACKGROUND OF THE INVESTIGATION

The working conditions in forestry differ greatly in comparison to the other fields of productive activity, because of different work and work place conditions. Forest work is the most strenuous job and demands very high of workers both in their physical strength and fitness. The operation of tree harvesting is especially notorious for having a very high physical workload on the workers in relation to work performance. High physical workload means increased stress on cardio-vascular system, musculo-skeletal system and high drain of energy from the workers body, resulting in to reduced daily work hours, poor labour productivity and early invalidity of the workers.

Besides personal capabilities of the workers, there are many situational and material factors in forestry which affect the work output. These are climate, terrain, crop and species, tools, training and nutrition of workers, which play an important role in deciding the magnitude of physical effects of work on the human body and material advantages.

The present state of forest work in almost all developing countries is very poor. The workers work under very difficult conditions, on a very low wage rate, with primitive tools and no vocational training, resulting into an impaired labour productivity and very low socio-economic status. There is an urgent need for studies and research for the improvement of work and worker in these countries. Comparison of working techniques and tools and ergonomic research are essential for the optimization of "Man-Task System" and to improve the socio-economic conditions of forest workers by way of reduced physical workload and increased work productivity.

Forest areas of Pakistan are unique in the world for presenting the worst combination of manual, technical, climatic and terrain conditions. Poor health and nutrition has resulted into a low work capacity of workers and adverse work conditions, inefficient tools and lack of proper training are the factors conducive to a very high physical workload and very low labour productivity. With the result that the forest workers in Pakistan stand at the lowest tier of the society.

Within the aims of labour policies and overall national development, it is essential to look for the possibilities of improvement of forest work and the worker in Pakistan. With these objectives in view, the present study has been undertaken and it is a small but the first attempt to estimate the physical workload and technical labour productivity in timber harvesting in the country. A comparison of conventional and improved tools has also been included for their effectiveness in reducing the physical workload and increasing the technical labour productivity for the option of better alternate tools and methods.

1.2 FOREST AND FORESTRY IN PAKISTAN

1.2.1 The Country in general

Pakistan is a sub-tropical country, stretching between 24° and 37° N latitudes and 61° and 75° E longitudes. It presents a variety of climates and vegetation types, which are mainly because of ecological changes with increasing altitudes from south towards north. Southern lowlands interspersed with tracts of sand, merging into alluvial plains, sub-himalayan plateau and the extensive chains of high Himalayan mountains in the north, with peaks more than 8000 m high and permanent snow fields, present a unique feature. These topographic variations are also accompanied by the changes in climate. In south there is a long spell of hot summers, with a mild but short lived winter season.

In the central plains, the summers are extremely hot, with day temperature often shooting upto 45° C in the month of June, while winters in these areas are also very distinct and chilly. The winter season in the northern and north western mountain country is very cold with mild and pleasant summers. The average rainfall in the south is about 100 mm and it increases with the increasing altitudes upto more than 1500 mm in the northern hills. The bulk of the rains is received from the south western monsoons, from the Arabian sea in the months of July and August, while heavy winter snow in high mountains characterizes the landscape. Most of the country falls in arid and semi-arid zones, with a natural vegetation of tropical thorn bushes and small trees, while the sub-tropical and temperate zones in Himalayan foothills and high mountains, have coniferous tree species as dominant natural flora.

In 1981, Pakistan (including Azad Kashmir) had a population of 86.32 million people, and proportion of urban and rural population was about 28 and 72 %, respectively. If projected at a growth rate of 3 % per annum, the present (1985) population status is about 98.16 million, with about 112 persons/km² (Table 1).

Agriculture is the backbone of the national economy, practiced on 22.9 % (Table 2) of the total land area mostly with irrigation, contributing about 22 % of the GNP and employing 55 % of the labour force. The GNP at current prices (1983 - 84) is estimated at 416.2 billion Rupees and per capita income at Rs. 4,530 (Source: Pakistan economic survey, 1983 - 84).

Administratively Pakistan is divided into four provinces. Province of Sind in south east with its capital at Karachi, province of Punjab in north east with its capital at Lahore, province of North West Frontier in the north west, with its capital at Peshawar and the province of Baluchistan in south west with its capital at Quetta. Each province is internally independent, headed by an executive head (governor), appointed by the Federal Government in Islamabad and a constitutional head (chief minister), elected by the public.

Table 1: Population of Pakistan

Province/territory	1981 Census (millions)	Growth rate %	Projected population in June, 1985 (millions)
N.W.F.P.	13.06	2.18	14.32
Punjab	47.45	2.7	53.21
Sind	18.97	3.5	21.99
Baluchistan	4.30	7.0	5.16
Northern Areas	0.56	3.6	0.65
Azad Kashmir	1.98	2.8	2.23
Total	86.32	2.988	98.16

Table 2: Land use classification

Land Use	Area (million ha)	% of total land area
Cultivation	20.15	22.9
Culturable waste	11.67	13.3
Not available for cultivation	18.86	21.4
Area under the control of Forest Departments excluding the range lands	4.37	5.0
Un-reported or unclassified area	32.93	37.4
Total	87.98	100.0

1.2.2 Forest and Forestry

Forestry in Pakistan is a provincial discipline, headed by a territorial chief known as "Chief Conservator of Forest", sitting in the capital of respective province and working under the provincial ministry of food and agriculture. The seat of a federal body responsible for inter-provincial coordination and cooperation with the other countries is in Islamabad and is chaired by the Inspector General of Forests. For complete hierarchical order, see Fig. 1.

Productive Function of Forest

The forestry and forest like in any other country has to play its material and non-material roles in Pakistan. Unfortunately the area under forest is very low, estimated as 4.96 % (AMJAD and KHAN, 1984) of the total land area of 87.98 million ha (Table 3) and is 41.3 % of the total area (10.4 million ha) (AMJAD and IQBAL, 1982) under the control of forest departments. Remaining 58.7 % (6.1 million ha) are managed as rangelands, without any tree growth. Coniferous forest, riverin forest and irrigated plantations are the major source of timber and firewood supply in the public sector, sharing as 41.4 %, 6.8 % and 4.5 % of the total forest area, respectively (Table 4). Rest 47.3 % is either scrub on the dry low hills or as littoral swamp vegetation on the sea coast. About 225 thousands m³ of timber and 250 thousands m³ of firewood (AMJAD and KHAN, 1984) are anually harvested from the state forests and nearly 5.9 times the quantitiy of timber and 77.5 times the quantity of firewood from farmlands.

Fig.1: ORGANIZATION OF FORESTRY IN PAKISTAN

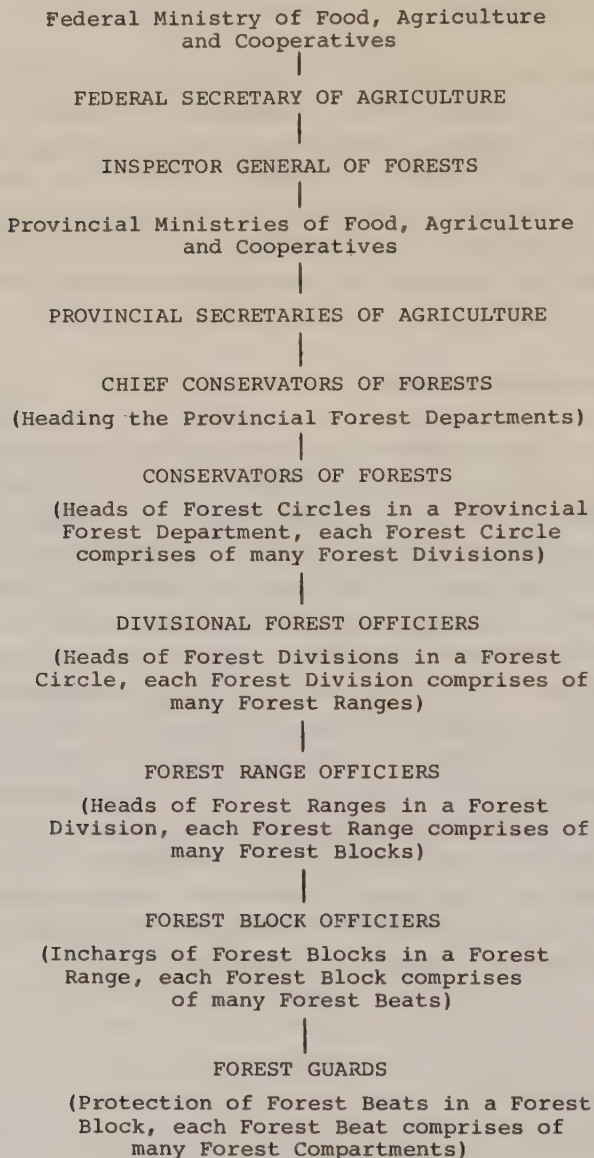


Table 3: Forest Area

Province/ territory	Total land area (mill. ha)	Forest area (mill. ha)	Forest area % of total area	Per capita forest area (ha)
N.W.F.P.	10.17	1.16	11.4	0.08
Punjab	20.63	0.55	2.7	0.01
Sind	14.09	0.59	4.2	0.03
Baluchistan	34.72	0.72	2.1	0.14
Northern Area	7.04	0.94	13.4	1.54
Azad Kashmir	1.33	0.41	30.8	0.19
Total	87.98	4.37	4.96	0.05

Table 4: Forest Area of Pakistan and Azad Kashmir by Vegetation Type

Vegetation type	Area (million ha)	% of total
Coniferous	1.78	41.4
Irrigated Plantations	0.19	4.5
Riverine	0.29	6.8
Scrub	1.72	40.0
Coastal	0.28	6.6
Others	0.03	0.7
Total	4.29	100.0

The important softwood species are deodar (Cedrus deodara), fir (Abies pindrow), spruce (Picea smithiana) and two pine species (Pinus Wallichiana and Pinus roxburghii), while the important hardwood species are shisham (Dalbergia sissoo), mulberry (Morus alba), babul (Acacia nilotica) and poplars (Populus sp.).

The cause of low forest area in Pakistan is the destruction done to the forest at the hands of repeated migrations of settlers and invasions of devastating armies over thousands of years. Misuse and over-utilization has resulted in the transformation of once thick forest growth into barren lands and bare mountains. Moreover, before 1947 Pakistan remained a part of Mughal and British Empires of India, which then had a reasonable percentage of forests. The timber demands were met mostly from those areas which are not now in Pakistan. The timber being quite common and cheap those days and the people could not think of it to be a valuable commodity. Therefore, they developed nonconservative habits in the use of wood. This situation did not remain long and in 1947, Pakistan emerged as an independent country with very little forest and a huge population having the habit of lavish use of timber. Low supply and high timber demand, resulted in an extra pressure on the already overutilized and meagre forest resource. With the result that the timber has become a very scarce and priced commodity.

The domestic timber production is only enough to cater 69.9 % of the local needs, rest of 30.1 % is made up from the foreign imports of timber and its various products (Table 5). About 665 thousands m³ of timber and timber products are annually imported at a cost of 1,381 million Rupees, while the value of export of wood and wood products is only 176 million Rupees, mostly in the form of sport articles. The demand of timber in future years is expected to increase sharply because of growing population and rising standards of living.

Table 5: Annual timber demand and sources of supply

Source	Value (1000m ³)	%
1. Forests	225	10.2
2. Imports	665	30.1
(i) Timber round & sawn	196	
(ii) Wood based pulp, paper & panel products (roundwood- equivalent)	468	
3. Farm & wastelands (by difference)	1,320	59.7
Total	2,209	100.0

This acute shortage of timber has resulted into very high prices of this commodity. In the sale depots of Forest department, the average important hardwoods prices lie between Rs. 2,500 - 4,500/m³ and the average prices of important softwood species range between Rs. 2,000 - 3,500/m³.

Protective Function of Forest

The protective functions of forest are even more important for Pakistan than its productive and recreational functions. The vast mountainous territories in the north and north west constitute important watersheds drained by the river Indus, Jhelum and their tributories. Moreover, these are also the areas of high precipitation, with very steep terrain. Poor forest cover, damage to vegetation and defective agriculture in these areas has resulted into increased runoff and accelerated erosion.

This situation is not only the cause of erratic river flow and devastating floods downstreams, but also a serious threat to the functional life of two multimillion water reservoirs, built on river Indus at Tarbela and river Jhelum at Mangla, for the supply of irrigation water and electricity. Irrigation water is the blood stream for living and flourishing agriculture in Pakistan. It will be beyond exaggeration to say that Pakistan has got the most extensive irrigation system in the world, with a total length of main irrigation channels about 50,000 km (CHAMPION et al., 1965). For the efficient working of this system a regular flow of water in the rivers is a must. These rivers originate in the high mountains and get their water from melting of snow in the summers and rains. For the constant flow of water in these rivers, slow and steady melting of snow and controlled runoff is needed, which is possible only in the presence of adequate vegetation cover. But in contrast to it snow melts very quickly in summers due to very poor vegetation cover or no cover at all. Moreover, the situation gets worst by increased runoff during monsoon rains and steep nature of the terrain. With the result that the rivers in summer months often overflow their banks, because of excessive water and cause tremendous damage to the life and property. While in winters they do not have enough water to feed the irrigation system.

Accelerated erosion in the catchment and siltation of river beds in the plains is also a contributory factor to the frequency and severity of floods and changing of river courses. The eroded and transported material is not only damaging to reservoirs and agriculture down stream, but is also the most serious problem of mountain regions itself. Removal of top rich soil is a permanent loss. Revegetation of exposed bare rocks is impossible. Destruction of vegetation and accelerated erosion in these areas is a complex interaction of socio-economic, biotic, climatic and topographic factors. The graveness of the situation has already been realized and large scale watershed management programmes has been started nearly two decades ago, with the help of international bodies,

such as FAO and World Bank. The strategy of these programmes is the rehabilitation of vegetation, mainly through mass scale afforestation on private lands, control of erosion and runoff by engineering structures and improvement in the economic condition of the local inhabitants by increase in their income through planting of fruit trees, rather to practice the traditional agriculture.

Recreational Functions of Forest

The forests also afford recreational opportunities to the peoples living in towns and cities. The attitude of people towards recreation depends on their prosperity. The economic condition of the masses does not allow them to travel to far flung forest areas. The recreational facilities are availed only by well off city dwellers or the persons living near by the forests. The recreationists move to the hill stations to enjoy the scenic beauty of forest and landscape and mostly retire at headquarters in the cool and pleasant climate in summers. Very few people are fond of hiking, stroll through the forest and winter sports.

Forestry Operations

The major operation in the state forests is timber harvesting which is carried out either by the semi-autonomous provincial bodies, such as "N.W.F.P. Forest Development Corporation" in the province of North West Frontier and "Azad Kashmir Logging and Sawmilling Corporation" in Azad Kashmir or provincial forest departments themselves or through a separate intra-departmental set-up in the provinces of Punjab and Sind. The corporations work to harvest softwood species in the mountainous regions and purchase standing trees from the forest departments on negotiated rates. Tenders are floated by these corporations to the private contractors for carrying out different operations, such as felling and conversion of trees, minor and major transport of timber

upto transit and sale depots. Contracted transport is also supplemented by departmental truck when ever needed. From the sale depot the timber is sold out by open auction to the consumers.

Harvesting of timber is almost continuous throughout the year except May and June in the sub-tropical chir pine forest as a rule (fire season), while heavy snow restricts such activities from the months of December to March in temperate forest. In irrigated plantations the harvesting of timber is in progress from August to February, while all such works are to be completed upto April, before the onset of floods in riverin forest.

The other forest works are nursery, regeneration and tending operations, which are more or less carried almost in all seasons of the year, except afforestation with a prime time in springs and monsoons. These operations on account of being limited in scale and more technical in nature, are directly carried by the staff of the forest departments through the labour engaged on daily wage basis.

All the forest operations are manual with the help of most simple hand tools.

1.2.3 Forest Labour

According to AMJAD and IQBAL (1982), there are about 600,000 workers employed in forestry and wood based industry in Pakistan. In forestry alone 340,500 work to perform different operations both on state forests and private farmlands and about 290,000 carry out timber harvesting for about 28,900 thousand man days. Of these 19,000 work in state forest and 271,000 on private farms.

Types of Forest Labour

The following categories of labour working in the public forests can be recognized based upon their skill, methods of working, source, time of availability and relation with the forest administration.

- a) **Local Villagers:** This category of labour is seasonal, comprising of the **farmers** living near by the forest areas. As a requirement of farming they know the use of axe, saw and soil working tools and work in the forest when off from their agriculture practice. They work to carry out a wide variety of operations, such as timber harvesting, road construction and repair, nursery, regeneration and tending operations. This type of labour though easily accessible, varies greatly in its supply with the alternating periods of surplus and scarcity, governed by crop sowing and harvest.
- b) **Nomadic Labour:** These are either **Afghans** or come from the tribal areas between Afghanistan and Pakistan. In winter months they move to the plains of provinces of Punjab and Sind along with their families and animals. They live in the forest in temporary huts and work to harvest hardwood species in irrigated plantations and riverin forests. These are very hardy people and their lack of skill in timber harvesting is well compensated by their body strength. They work mostly for winter months and move back before the onset of summers. A local nomadic labour called "**Labanas**" work more or less on the similar lines in lower Punjab and Sind.
- c) **Forest Settlements:** These are known as "**Beldars**" which permanently live in the forest areas of Punjab (irrigated plantations) and in return to certain concessions, like free accommodations, a piece of land, firewood and certain number of cattles are bound to perform different forestry operations when desired. Their history goes back to the time of establishment of first

irrigated plantation of Changa Manga in the year 1866, to meet the firewood needs of newly colonised areas with the extension of irrigation system. This type of arrangement proved very satisfactory to ensure sustained labour supply for the efficient execution of forest operations. At that time forest work was their only mean of sustenance, but now a good deal of them work outside the forest due to a high increase in their number.

- d) **Mountain Forest Labour:** This category of workers belong to the north west hilly country of Pakistan. They work for forest contractors to harvest the timber in the high hill forests of conifers. They are comparatively better skilled and besides logging and minor transport, also carry out hand and machine conversion of timber into scants in the forest, for their easy carriage by means of animals. They keep on moving from forest to forest after work. In winters they work mostly in sub-tropical chir pine forest and in summer months in temperate forest.

System of Work and Payments

The forest labour who carry out nursery work, regeneration operations and construction and maintenance of engineering structures work directly for forest department and are paid on **time basis** (daily wage) for work days of eight hours duration. The ground for such payments is taken from the approved labour wages in the nearby population areas. The labour who carry out timber harvesting, work either direct for forest department or for the forest contractor in riverin forest and irrigated plantations, or solely for the forest contractors in high hill forests of conifers. They work on **piece-rate**, which is verbally decided between employer and labour, directly or through a labour contractor in visual consideration to crop and work conditions.

Some units of work for the purpose of piece-rate are summarised below:

- Felling/tree, according to a maximum of 2 - 3 DBH classes.
- Per cft. or per log converted, including debranching, debarking, cross-cutting and engraving of number and identification marks.
- For hand sawing in the forest, per cft. of sawn timber irrespective of size and per slab with about two length classes.
- Per stack of firewood converted.
- Likewise transportation and stacking rates (manual, animal and motor transport).

In the high hill forests, the forest contractor arranges the labour through a labour contractor. The labour contractor personally known each worker and informs them about the work, perspective rates and advances them money as surety of job and payments and in return charges commission on their earnings. The labourers receive payments either fortnightly or monthly in cash. During work the workers of category (b) and (d) live in the forest for weeks in temporary self made huts and mostly work from dawn to dusk with a lunch break at noon and Friday as holiday. They always work in parties ranging mostly from 2 - 5 persons.

Education and Training

There is no formal vocational training for the forest workers, in work methods and use and maintenance of tools. They know the use of axes, pick-axes and saws as a requirement of agriculture and village life and are further trained on the job. Those who inherit forest work as their family profession, on the job training starts from early youth by their seniors.

Tools

The tools used by the forest workers are simple hand tools made from the used parts of vehicles and old rails, without any strict design and quality considerations. The most commonly used tools are as follows:

- Nursery and Regeneration Tools

- . Pick-axes: With various blade widths according to the nature of soil
- . Shovels: With various blade widths and handle lengths

- Harvesting and Timber Conversion Tools

- . Axes: Various shapes and weight classes
- . Crosscut saws: 5 feet length
- . Frame saws: 4 - 5 feet in length with 10 cm blade width for hand conversion of logs in the forest
- . Hammers: Steel head, 5 - 10 kg in weight
- . Wedges: Steel, of various sizes
- . Bill hooks: For conversion of small firewood and cleaning operations

Productivity and Earnings

Lack of proper training, inefficient and deficient tools, poor nutrition and health standards, coupled with difficulty of terrain and poor living facilities in the forest result in a very low labour productivity, roughly estimated to be not more than 1.0 m³/man/day (coniferous round wood) with timber harvesting in any case. Low work productivity not only unnecessarily delays the timber harvesting work but is also a cause of **poor income** for the worker itself. Due to non-availability of reliable information on the labour earnings, it is difficult to quote a numerical figure. But when considered in view of productivity and prevailing low wage rates, it can be said with certainty that forest workers in Pakistan stand among the lowest wage earners of the world.

Social Benefits

There exists no system of life insurance, medical facilities and accident benefits for the forest workers. In case of accident, disability or death, the forest contractor may pay an unfixed amount of money only on humanitarian grounds and to maintain his reputation among the workers. This amount never exceeds a few thousand Rupees in any case. But even these meagre compensations are unimaginable when a labourer is working direct for the forest department. Such payments are only lumpsum for the occurrence of incidence, but does not guarantee the cost of absentees from work due to injury or sickness. In hill forest the workers always work in groups and have developed a system of mutual help among themselves. When a worker is injured or sick, the other members of the group keep on paying his share from their earnings till then he stays in the forest.

1.3 NEED FOR THE IMPROVEMENT OF FOREST WORK IN PAKISTAN

Inspite of the fact that forest labour is an important component of all forestry activities, little attention has ever been paid for the betterment and improvement of this aspect in Pakistan. Low labour productivity, poor working conditions, bad health, disease, mal and undernutrition, inefficient and insufficient tools and lack of proper training are all the factors conducive to a very low socio-economic status of forest workers. With the result that they work at a subsistence level and it will be beyond exaggeration to say that they work at the lowest wage rate and under the most difficult and poor working conditions.

This cycle of events has reached an equilibrium state between productivity and earnings and socio-economic condition of the workers. It is an important technical and human problem and needs due consideration at the managerial level. The ways and means are to be looked for the betterment of work and the worker.

On account of all operations being manual, forest labour is the biggest potential in the direction of intensification of forest work, through better labour management practices. In the following paragraphs some of the aspects of forest labour in Pakistan are outlined along with the need for practical measures, studies and research for its improvement possibilities.

The available informations about the forest labour in the country are very sketchy and fragmentary. For any future planning and to ascertain the line of action in the direction of forest labour improvement, it is essential that certain basic statistics should be available about the exact number, age, skill, tools, working days/year, earning, health, endemic diseases, nutrition status, accidents (STREHLKE, 1971) and types of operations performed by the forest workers.

All forestry operations in Pakistan are carried out almost manually. The tools used are centuries old, which not only are poor in material but also in design and state of maintenance. These inefficient and insufficient tools make the job very sternuous with a very high physical workload.

The situation is worsened by the unfavourable climate. As the forest work is always carried out in the open and the workers are exposed to the adverse climatic conditions. High heat of the day and a high physical workload, cause a marked decrease in the daily work hours and ultimately reduced labour productivity.

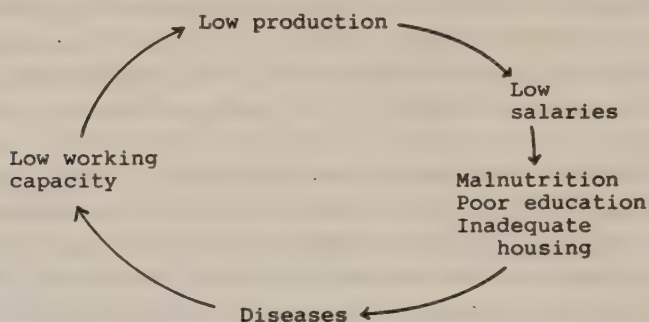
There is a good scope for the introduction of improved tools both in quality and design. These tools will prove of great help in increasing the labour productivity and decreasing the physical workload or keeping it at a comparable level. Studies on ergonomics for the optimization of "Man-Task System" (ANON, 1979, ZANDER, 1979) and to break the vicious circle of low productivity, low income, malnutrition, disease and low working capacity (ELGSTRAND, 1982) are strongly emphasised.

Another aspect of forest labour in Pakistan is food. Good, adequate and balanced food is very essential for forest work to meet the daily energy requirements for normal performance (ABELI, 1979, STAUDT, 1984). A forest worker needs a daily energy intake of about 16-20 MJ (LOON, 1982, CHRISTENSEN, 1964, ANON, 1961). But in contrast to it, the present state of forest labour nutrition in Pakistan is very poor. The food is inadequate and mostly consists of carbohydrates and fats, with a very little or no animal protein at all. Under and malnutrition affects the health and working capacity (CHRISTENSEN, 1964). Increase in the income of forest workers and their instigation to take enough and balanced food through education is a plausible solution to overcome the problem of nutrition in forest work.

Living environments of the workers are highly unhygienic and polluted, mosquitoes are in large numbers, because of stagnant water ponds all around. Drinking water is heavily contaminated, with the result that the diseases like malaria and dysentery are very common and are the main cause of absentees from the work. Medical facilities are very meagre, therefore, disease and death especially of infants is rather a routine of common day life.

Disease and death has got far reaching socio-economic consequences. Disease self means absentees from work or even death - no money for the family, treatment self or of a family member - costs money, weakness due to disease reduces the work productivity - less money, birth and care of a child - costs money, disease and death of a child - again an economic and social loss. This situation is very well explained by the "Economic Cycle of Diseases" (ELGSTRAND, 1982) and is denoted as vicious circle of low productivity, low income, malnutrition, disease and low working capacity (Fig. 2).

Figure 2: The so-called "Economic Cycle of Diseases"



Studies are needed for the improvement of living and working conditions (LOON, 1982, ZANDER, 1979) of forest workers.

There is no medical and social security coverage for the forest workers. In case of disease the worker has to bear the expenses of his treatment and moreover additional loss because of absences from the work. In case of injury, disability or death, the worker or his dependents may get a very meagre amount from the forest contractor, which is not because of any legal obligation, but only on humanitarian grounds. Even this much a worker cannot expect when he is working directly for the forest department, because of lack of such provision in the government rules. There is an urgent need for the formulation of a legislation and making of laws and by-laws for providing social and medical security to the forest workers.

There exists no system of formal training of forest workers, in proper work methods, maintenance of tools and personal safety. Lack of proper training results into low labour productivity, poor maintenance of tools, high physical workload and high chances of accidents. Programmes for the forest labour training in the methods of work, maintenance of tools and personal safety are an urgent need of the time.

The workers work without the use of any protective accessories and clothing, such as gloves, boots and working suits. Normally they work bare footed, therefore, the injuries to the hands and feet are very common. Moreover, the workers are never provided with the first aid material. The wounds are dressed with ashes, pine resin and old unhygienic cloth without the use of any anti-septic medical preparation, with the result that the wounds often get infected and remain a source of trouble for long times. Conventional protective clothings cannot be used because of climatic constraints. But there is a good scope for the introduction of properly designed clothings and protective accessories suited to the local climate. Provision of proper first aid material at work place will reduce the severity of accidents.

1.4 AIMS OF THE STUDY

The investigation at hand is to be seen as first, though small step for the improvement of forest work in Pakistan. The study is focussed on the measurement of physical workload and technical labour productivity in timber harvesting with the following objectives:

- Scientific estimation of **physical workload and technical labour productivity** in tree felling and conversion in the irrigated plantations in Pakistan, in relation to different influencing factors, such as tree species, tree parameters and work party sizes.
- Effectiveness of additional inputs as **improved tools and training of forest workers** will also be tested in consideration to enhanced output of work and ergonomic benefits.

- Based upon the physical workload, the results will identify the **most difficult phases of work, optimum work party size** as suggested by a decrease in physical workload and an increase in technical labour productivity. Effect of species and tree parameters on the time demand with respect to different work elements and labour productivity shall also be discussed.
- The study is first of its kind in the country and the findings will serve as guide lines for the future activities in the direction of intensification of forest work.

The proposed study is the first one dealing with physical workload and technical labour productivity in timber harvesting in Pakistan and the readers will repeatedly come across with these terms. Therefore, for the ease of readers to understand the work fully and to appreciate its usefulness, two special chapters on productivity and workload have been provided in the text. Chapter No. 2 deals with the different types of productivity in forestry, factors and methods of its improvement. While chapter No. 3 discusses the workload, its types, indicators and limits for sustained performance.

2 PRODUCTIVITY

2.1 KINDS OF PRODUCTIVITY

Productivity (P) is defined as an inter-relationship, between production results (R) and employed factors of production (F) (SPEIDEL, 1963), Fig. 3:

$$P = \frac{R}{F}$$

Full productivity (total productivity, value productivity) is calculated by expressing the production results in monetary units:

$$\text{Full Productivity} = \frac{\text{value added}}{\text{Sum of input factors}}$$

The **technical or partial productivity** is shown by the quotient in which production results are expressed in natural units:

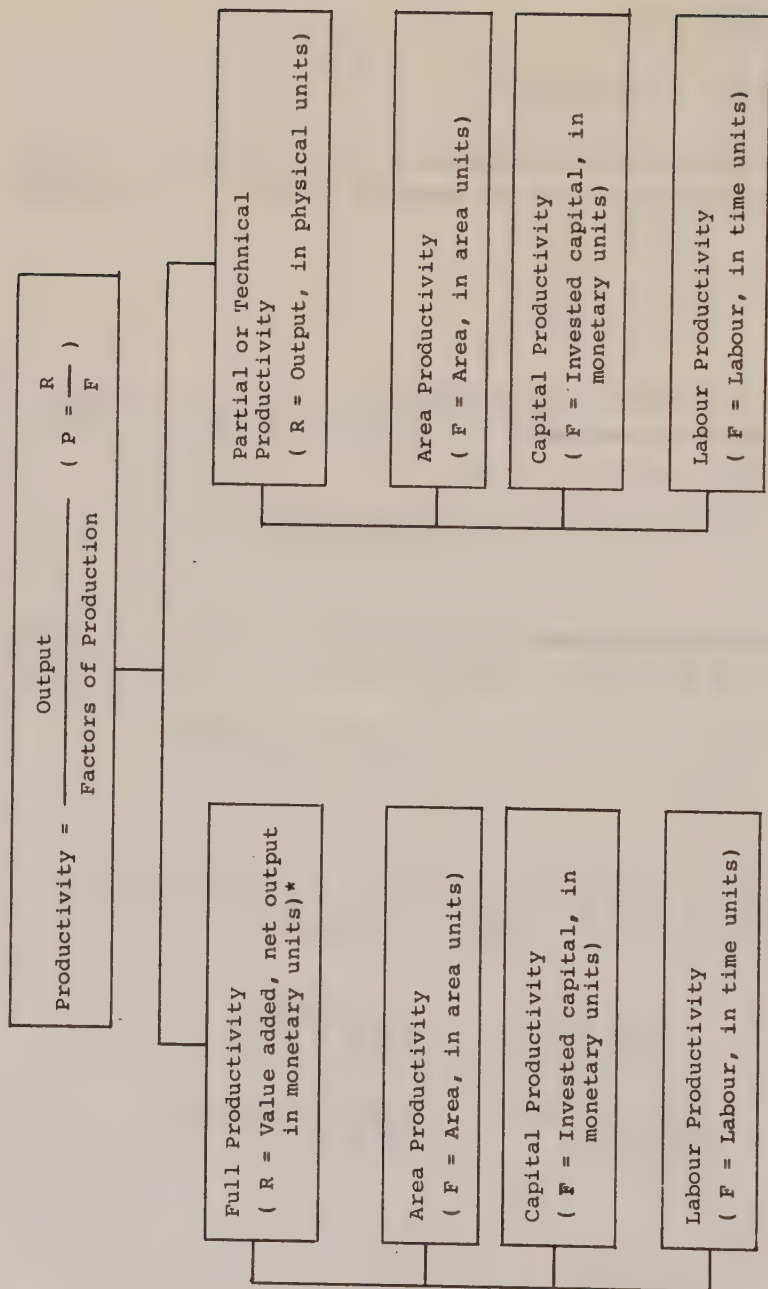
$$\begin{array}{l} \text{Technical or Partial} \\ \text{Productivity} \end{array} = \frac{\text{Quantities produced}}{\text{Sum of input factors}}$$

By using the work time (A) as denominator in the above two equations, full labour productivity and technical labour productivity can be calculated, respectively.

$$\begin{array}{l} \text{Full Labour} \\ \text{Productivity} \end{array} = \frac{\text{value added}}{\text{Sum of A}}$$

$$\begin{array}{l} \text{Technical Labour} \\ \text{Productivity} \end{array} = \frac{\text{Quantities produced}}{\text{Sum of A}}$$

Fig.3: Types of Productivity (after SPEIDEL, 1963)



*) Value Added or Net Output

= Gross Yield - (material inputs + contracted services + depreciation)

The units of time used may be an hour, day, week, month or a year, while units of production can be any physical quantities in number, weight, volume and area.

There can arise a confusion in the use of different time units like a day, an hour, a minute and so on. To overcome the controversy in taking the meanings of different time units, SAMSET et al. (1978) presented a time study concept for the different time units, detailed as under:

Time Study Concepts	Units of Time				
	Days Work (d)	Hour (h)	Minute (min)	1/100 min (cmin)	Second (s)
Total time (To)	d To	h To	min To	cmin To	s To
Work place time (Wo)	d Wo	h Wo	min Wo	cmin Wo	s Wo
Effective time (E)	d E	h E	min E	cmin E	s E
Delay time (D)	d D	h D	min D	cmin D	s D

Energy Productivity

In the last few decades, energy consumption has increased many folds, especially in developed countries, due to expansion of industry and mechanization of different work operations. Moreover, during this period the prices of oil, as an important source of energy, on the international market have also gone very high. Under these conditions the energy inputs have become a strong determinant of economics of different production processes. Therefore, energy consumption in kWh is also taken as a factor of productivity.

Very few people are interested in the absolute values of productivity measurement (SPEIDEL, 1983 and GRAMMEL, 1978), but the changes in productivity over a definite period expressed as **Productivity Index (PI)**:

$$PI = \frac{P \text{ (new results)}}{P \text{ (base value)}} \times 100$$

Comparison of productivity indexes show, in which percentage the productivity has increased (Geiger, 1960) over a time period with the improved and changed factors of production.

For example the technical labour productivity in timber harvesting with conventional tools is 0.249 m³/man hour (base value) and improved tools gave a technical labour productivity of 0.307 m³/man hour. To see the change in productivity with the improved tools, the productivity index is calculated as follows:

Productivity Variable	TLP = m ³ /man hour		Productivity Ind. x = $\frac{\text{New results}}{\text{Base value}} \times 100$
	Base value	New results	
Total volume/ Total work time	0.249	0.307	123

The productivity index in the above example came out to be as 123. It means that improved tools caused a technical labour productivity increase of 23 % over a base value of 100 for conventional tools.

The productivity is just like a measuring stick for the technical achievement (WEIZÄCKER, 1966 cited by GRAMMEL, 1978) of an enterprise. Technical labour productivity and full labour productivity

and their changes are the essential basis for enterprise economics and for the decisions of enterprise politics, especially in work planning, work volume and work force requirement, testing of workers capacity in the interest of enterprise and above all to maintain the sustained performance of workers. Use of productivity index is a useful tool for the settlement of work contracts (GRAMMEL, 1978), testing of improved work techniques and optimum degree of mechanization (SPEIDEL, 1983). The level of productivity affects not only the personal security and well being of the individuals (GUZZO and BONDY, 1983), but also the cohesiveness and integrity of the society.

In forestry mostly the technical labour productivity (partial productivity) is measured (SPEIDEL, 1983), expressed in output units as cubic meters, running meters, square meters, hectares and number of pieces produced etc. and the employed factors of work are labour wage hours, machine hours or even per shift or per day of work.

In timber harvesting the technical labour productivity is taken either as a collective figures for all the operations between a standing tree and timber ready for sale at the marketing site, or it may be calculated for individual operations as primary felling and conversion, minor and major transport.

Given below is an example for the calculation of technical labour productivity with respect to total work time and effective time for different sub-operations in timber harvesting:

Example for calculating technical labour productivity for different sub-operations in timber harvesting.

Sub-operations	Time consumed min/m ³		Technical Labour Productivity m ³ /hour	
	Effective time	Total work time	Effective time	Total work time
Felling	12	18	5.00	3.33
Delimbing	28	39	2.14	1.54
Cross-cutting	22	30	2.73	2.00
Minor transportation	33	45	1.82	1.33
Piling along the forest road side	15	21	4.00	2.86
sum/average	110	153	0.55	0.39

m³ = cubic meter solid volume outside bark. When using other indications, a definition should be given in each case.

2.2 PRODUCTIVITY AND UNIT COSTS

The improvement in productivity is an achievement for an enterprise and is the best guarantee for its economic viability. The productivity improvements are said to exist (GUZZO and BONDY, 1983), when output increases relative to input costs or when input costs decline relative to output. In both these situations whether it is an increase in the units of production or a decrease in the production costs means a reduction in the cost/unit of production. So the unit cost is a single criterion of productivity achievement with any of the above mentioned alternatives.

Given below is an example for calculating unit cost in timber harvesting:

Cu = harvesting cost per unit (Rs./m³)

TLP = technical labour productivity (m³/man hour)

Ch = cost per hour (Rs./hour), including wages, social benefits as well as cost of tools

t = time consumption per unit (min/m³)

the following relation exists:

$$\begin{aligned} \text{Cu} &= \frac{\text{Ch}}{\text{TLP}} \\ &= \frac{\text{Ch} \cdot t}{60} \end{aligned}$$

For example the harvesting cost/hour increases at a rate of 12.4 % and technical labour productivity increases at a rate of 23 %. What will be the rate of change of harvesting (Cu) cost/m³?

Formula:

$$P_{HC} = 100 \left(\frac{100 + P_{Ch}}{100 + P_{TLP}} - 1 \right)$$

where P_{HC} = rate of change of harvesting cost/m³ as percent

P_{Ch} = rate of change of cost/hour as percent

P_{TLP} = rate of change of TLP as percent

Calculations:

$$P_{HC} = 100 \left(\frac{100 + 12.4}{100 + 23} - 1 \right)$$

$$= 100 \left(\frac{112.4}{123} - 1 \right)$$

$$= 100 \left(\frac{112.4 - 123}{123} \right)$$

$$= 100 \left(\frac{-10.6}{123} \right)$$

$$= 100 (-0.086) = -8.62 \%$$

So the harvesting cost/m³ (Cu) will show a reduction of 8.62 %.

2.3 FACTORS AFFECTING TECHNICAL LABOUR PRODUCTIVITY IN TIMBER HARVESTING

As already discussed we need two parameters for the calculation of technical labour productivity in timber harvesting. One is the material outcome of work as m³ of timber and the other is work duration to produce this quantity of timber. The relationship between production and work time, i.e. technical labour productivity, does not remain constant, but is subject to vary for different persons, tools, techniques, crop and work place conditions. Given below are the factors, which affect technical labour productivity in timber harvesting:

- Personal Capabilities of Workers
- Conditions of Workplace
- Crop Features
- Quality of Work Organization
- Technical Equipment
- Work Requirements.

Each of these factors is further elaborated as follows:

- Personal Capabilities of workers
 - . Physical build-up
 - . Nutrition and clothing
 - . Attitude towards work
 - . General and professional training
 - . Social benefits
 - . Rate and System of wage
- Conditions of Workplace
 - . Terrain features
 - .. Slope
 - .. Surface features

- . Climate
 - .. Temperature
 - .. Air humidity
 - .. Air movement
 - .. Rainfall or snowfall
- Crop Features
 - . Cut/unit area
 - . Tree species
 - . Tree features
- Quality of Work Organization
 - . Work organization according to time and locality
 - . Work sequence
 - . Safety at work
 - . Living facilities
- Technical Equipment
 - . Provision of proper and adequate tools
 - . Possibilities of mechanization
- Work Requirements
 - . Number and quality of work elements
(debranching, debarking etc.)
 - . Timber sizes
 - . Adherence to special sizes, strict observance of
top diameter.
 - . Other operation like extraction included or not.

2.4 POSSIBILITIES TO INCREASE TECHNICAL LABOUR PRODUCTIVITY IN TIMBER HARVESTING

With the pace of development the demand for increase in labour productivity is also rising. This is important to maintain an adequate supply of raw material to different industries and also for the cheaper production of goods and economic viability of different production concerns. Moreover, the costs of production process per unit time keeps on increasing with the passage of time and it is needed that the productivity should outpace the costs or at least remain in balance with them.

The productivity of an organization is principally determined by the organizational technology and job performance of its employees. In highly mechanized operations, change in technology is the most powerful determinant of productivity (GUZZO and BONDY, 1983), while in operations with more manual inputs, substantial increase in labour productivity is achieved by improvement in the workers performance.

Workers performance is a product of workers capabilities and motivation. The manual and technology factors in their harmonious combination can only guarantee for optimum results. Productivity increase upto 200 % and a cost reduction upto 50 % has been achieved in many countries (SUNDBERG, 1974) through work studies, research, training and improved planning procedures. In the paragraphs to follow different possibilities of improvement in technical labour productivity with particular reference to timber harvesting are discussed.

2.4.1 Education and Vocational Training

The vocational training is an organizational practice whereby the workers are educated with respect to specific skill deemed central to their job (GUZZO and BONDY, 1983). Vocational train-

ing of forest workers in proper work methods, use and maintenance of different tools, personal safety and ergonomics is essential to increase their performance and efficiency (ANONYMOUS, 1974, EISENHAUER, 1979) and also to make forestry more attractive to potential workers and less cumbersome to those who are already employed in it (ANONYMOUS, 1979).

Improvement of technique and introduction of new tools is essential for higher work performance, which is only possible through training programmes in new techniques and use of improved tools for increased productivity and to compensate the higher costs so incurred. The use of power chainsaw has become very common in almost all industrial countries and some of the developing countries, because of its much higher performance. But to work with a power chainsaw is not a simple matter. If not fully understood, it can prove to be a dangerous companion with a very high risk of accidents and at the same time posing serious ergonomic threats to the user. Special and intensive training is essential in the use of this tool for its optimum and safe utilization.

Proper tool maintenance is another aspect of vocational training of forest workers. Well maintained tools not only give a higher work performance, but also make the work more easy by reducing the physical workload on the worker. In a study on tools and ergonomics in Indian logging operations (HANSSON et al., 1966), it was found that improperly maintained saws for the same energy consumption gave a performance only 50 % of the properly maintained ones. Training in the maintenance of saws and proper work methods resulted into an increase in work productivity by about 15 % (SUMANTRI, 1979) in the teak plantations in Java.

Forest work is the most hazardous job with very high chances of accidents and about 80 % of these are because of human failure (ANONYMOUS, 1960). If a comparison of accidents statistics in forest work is made the rate of fatal accidents in developing

countries is 10 times as high as in industrial countries (ANONYMOUS, 1974). This big difference is only because of better training of forest workers in industrial countries, even though the workers in industrial countries have more potential danger of severe accidents (LAGERLÖF, 1979) on account of a very high degree of mechanization. Moreover, two third of the time lost in forestry work is because of accidents and diseases (STAREK, 1985) and training programmes in ergonomics for forest workers resulted into a substantial reduction (OBLIVIN, 1985) in the rate of occupational accidents and diseases. Savings in work time because of a reduced rate of accidents and diseases accounts for increased work performance.

Training in ergonomics is also essential for optimum performance. Proper body posture at work and ergonomically designed work places greatly reduce the physical workload, with less fatigue, less rest breaks, increased work time and more work output. Physical training is also essential for improving muscular strength (TEIKARI, 1981) and physical performance of workers for increased productivity.

2.4.2 Institutions

Existence and role of national and regional research and training institutions is very essential for the improvement of work and worker. These institutions serve as nuclei for ergonomic research, teaching and training in different forestry operations. Ergonomics has to serve its widest role for the benefit of biological unit of work "the man" and the material outcome of the activity "the technical labour productivity". Ergonomic research has been defined as a precondition for the improvement of situation of working man as well as for the improvement of enterprise economy, by way of adequate design of organization of techniques (MUELLER-DARSS, 1979). Collection of informations on different aspects of man and work, their processing, dissipation and practical application of re-

sults into various work fields of forestry are the main function of these institutions.

The biggest draw-back in the initiation of activities for the improvement of work and worker in developing countries is the lack of basic informations for fixing the strategies for future improvement plans. Studies and research is to be organized and carried out by these institutions for the collection of data on the number, age, skill, tools, work days/year, earnings and types of operations performed by the forest workers in the country. Research in ergonomics is needed for the optimization for "Man-Task System" (ANONYMOUS, 1979, ZANDER, 1979) and for the improvement of living and working conditions of the workers (LOON, 1982). Estimation of physical workload, technical labour productivity, working conditions, endemic diseases and nutrition is also essential for the improvement of work and worker. Comparison of work techniques and tools in forestry should also be included in the research and training programmes of these institutions.

MUELLER-DARSS (1979) proposed the following plan of activities for an ergonomic research and training institution for tropical agriculture and forestry.

Research Unit

Physiological studies:

- physiological capacities
- living conditions
- climatic conditions
- nutrition
- endurance capacities

Psychological Studies:

- environmental influences
- qualification, intelligence and learning
- fatigue, accidents

- man-work relationship
- motivation, cultural background

Sociological Studies

- social structure of rural population
- living attitudes (background)
- mobility
- labour market

Work Studies:

- time
- working procedure
- work output

Technical Studies:

- adaptation and/or development of investigation equipment
- tools and machinery

Training Unit

- inventory of current tools and equipment;
elimination and/or supply according to the regional situation
(e.g. know-how of workers and personnels);
- inventory of services for tools and machinery;
- contacting manufacturers of tools and machineries, for ergonomic, technical and economical adaptations and improvement;
- survey of educational state of personnels and workers;
- formation of a training group for demonstration of "perfect and modern" work.

2.4.3 Improved tools

As the demand for wood increased the pressure for higher productivity prompted the improvement of old tools and development of new methods and equipment (GOLOB, 1981). The first tool used for wood cutting was axe, underwent many changes in material and de-

sign over a period of centuries. Introduction of cross-cut saw almost replaced the axe work and made the work less arduous with increased productivity. Crosscut saw was followed by bucksaw and bowsaw, which again had their own advantages. This all sequence of development is because of the constant human pursuit for better and efficient tools.

Improved tools both in quality and design and properly maintained, not only have a positive influence on work productivity, but also reduce the physical workload on the worker. In a study on tools and ergonomics in logging operations in India (HANSSON et al., 1966), it was found that the bowsaws gave a higher performance and less energy demands as compared to one- and two-men crosscut saws in felling and crosscutting of diameters upto 30 cm. Advantages of raker-tooth bowsaws were even higher than the peg-tooth bowsaws. Studies on the choice of technology in forestry in Philippine (LAARMAN et al., 1981) showed that the bowsaw is less than half as labour intensive as axe and by about 7 - 11 times less wasteful. Comparison of two-men crosscut saws peg- and raker-tooth (MALETA and SOOD, 1984, HANSSON et al., 1966), showed that the raker-tooth saw gave a higher output and lower energy consumption than the peg-tooth saw. Training and introduction of improved tools resulted into an increase of 33 % in labour productivity during harvesting of softwood species in Turkey (GÜRTAN, 1964).

Power chainsaw is a very efficient tool in felling and conversion of trees and has almost replaced all cutting tools in tree felling and conversion operations in industrial countries. Results of the studies on the efficiency of power chainsaw revealed that the power chainsaw gives a higher performance and less energy demand per unit area of cut in felling and cross-cutting as compared to the other cutting tools (HANSSON et al., 1966). The higher work performance of the power chain saw in timber harvesting is also supported by the results of the studies carried out in the plantations in Pakistan. These studies

(ANONYMOUS, 1984 b, AYAZ and SIDDIQUI, 1982) reported that power chainsaw is 2.6 to 3.5 times more efficient in felling and conversion of trees in comparison to axe and two-men cross-cut saw (peg-tooth), respectively.

2.4.4 Mechanization

Human capacity to perform physical work is limited, but the demands for higher labour productivity are always surpassing. Therefore, some helping means are needed to increase the sphere of manual activities. Mechanization of work operations is the only solution to bridge the gap between human limits of physical performance and higher labour productivity demands. Change in technology is the most powerful determinant of labour productivity (GUZZO and BONDY, 1983). The "axeman" of today controls a machine capable of productivity many times greater (GOLOB, 1981) than the productivity of the best axeman of the past. Sustained increase in labour productivity can be achieved (DUNLOP and DIATCHENKO, 1964) with the introduction of new machines and technology amounting to 64 - 74 % increase in productivity in different work fields.

Mechanization is the most effective tool for increasing the technical labour productivity and is more or less independent of socio-economic conditions of different countries. But full labour productivity of mechanization is highly variable because of difference in machine and labour costs among the countries. The industrial countries are the self manufacturers of machines and the machine costs seldom exceed 50 % of the total costs and the share of labour cost is more than half (SUNDBERG, 1974).

Employment of machines in industrial countries cut down the work time (STEINLIN, 1969) and result into a higher technical as well as full labour productivity, because of a saving in the labour costs. In developing countries the machines are imported and

equipment costs go up as high as 70 - 80 % and labour cost account only for 20 - 30 %. The use of machines although results in a higher technical labour productivity, but full labour productivity may not improve so much, because of cheaper labour cost factor and a saving in the labour cost due to mechanization may not significantly affect the full labour productivity index.

Another aspect of mechanization is its effect on employment. In Sweden the number of jobs was reduced from 230,000 to 100,000 (SANDAHL, 1974) with the introduction of machines in different forest operations over a period of 20 years. Developing countries are already facing a chronic problem of unemployment. Mechanization means more people will be out of their jobs. Therefore, the option for mechanization should only be made under very special conditions, otherwise the well trained workers, working with better tools, techniques and work conditions is a suitable compromise between employment problems and labour productivity in developing countries.

ILO (International Labour Organization) has carried out a number of case studies comparing highly mechanized operations with efficient manual work (cited by SANDAHL, 1974). Based upon the results of these studies, it is concluded that a combination of mechanized techniques at an intermediate technology level and improvement in labour intensive operations would be more economic than the use of highly mechanized technology.

2.4.5 Work Organization

The purpose of work organization in timber harvesting is to preplan the ways and means for the optimum use of available labour, machinery and tools for production in accordance with the specific task assigned (FRAUENHOLZ, 1978). Better work organization affects workers performance and is the job of forestry enterprise to estimate the size of work and available means.

Organization of work depends upon the level of education, competence of workers, wage system and the organizational climate (AGER, 1981). Better work organization increases labour productivity by better coordination, less interruptions and capacity to finish the work (FRYKMAN, 1980) in the allotted time period.

The following points are necessary for the organization of work in timber harvesting for optimum results:

- Determination of Size of Work:

Full informations about the stand and growing stock, such as species and sizes of trees, type of felling to be carried out and volume of timber to be extracted, nature of ground and silvicultural constraints.

- Means of Transportation and Communication:

Existing means of communication for the workers to the work place, distances involved, means of extraction of timber and their present condition.

- Determination of Work Crew Size:

In view of size of work and time period at hand, calculation of number of workers needed to complete the job. Volume of cut and the technical labour productivity are the basis for the estimation of crew size.

- Tools and Equipment:

Whether the tools and machines to be used in the timber harvesting work are available in sufficient number, their state of maintenance and readiness for use.

- Protection of Workers:

Arrangements for the protection of workers against heat, cold, rain and diseases.

- Organization of Working Hours:

Fixing the time of start of work and close of work to the best convenience of workers and for the mutual satisfaction of employer and employee. In hot seasons the work should confine to the morning and afternoon, avoiding hottest hours of the day (STREHLKE, 1974).

- Arrangements of Breaks:

Continuous working is impossible and the workers get exhausted very soon if the work is heavy. Sufficient breaks in number and duration are needed to rebuild the workers energy. In hot climates frequent and short breaks are essential to avoid over heating of the body than the less frequent but long breaks.

- Job Rotation:

Different work operations have different energy demands. In a work system some of the workers are permanently overloaded, while others enjoy a better work condition. Change of work among the workers is essential to give relief to the workers who have worked above their physical limits.

- Availability of Good Quality Drinking Water:

Under hot climates a worker consumes 5 - 10 litres of water per work shift (STREHLKE, 1974). It is difficult for each worker to carry this much of water daily to the work place. Supply of good quality of drinking water preferable containing 1 % salt, is essential to replenish the loss of water from the bodies of the workers and to avoid dehydration.

- Motivation:

Different psychological and material motivational factors affect workers performance. Handling of workers with the best leadership qualities, appreciation and participation of workers in work planning are some of the psychological aspects of work organization. Other monetary incentives are the rate and system of payments, possibilities of bonus, social benefits and medical

insurance for the workers. Provision of first aid kits to the workers will reduce the time of interruptions because of minor accidents.

2.5 COMPARISON OF TECHNICAL LABOUR PRODUCTIVITY IN TIMBER HARVESTING AMONG DIFFERENT REGIONS AND COUNTRIES

2.5.1 Importance

The objectives of international exchange of experience are to improve the technology and to reduce the economic gap among cooperating peoples and countries, as far as allowed by their local conditions. HILF et al. (1961) proposed an international productivity comparison among the forest workers of the different countries, for a selected work operation, which is important and as well common to the countries in question. Among different forestry operations the work of timber harvesting (without minor and major transport) offers good possibilities of such investigations. The purpose of proposed studies is to choose the best techniques and their application for increasing the labour productivity, either at comparable costs or at the reduced costs for increasing the economic standard of forest workers (HILF et al., 1954) in the developing regions of the world.

For a just comparison of performance of workers from different regions and countries, certain reservations need to be observed. Because the performance of workers not only depends upon their personal capabilities, but also on many other factors. These can be due to climate, tree species, work requirements and degree of mechanization.

2.5.2 Technical Labour Productivity in Timber harvesting in Pakistan in Comparison to Federal Republic of Germany

There exist no recorded figures on technical labour productivity in timber harvesting in Pakistan. This is because that no body ever realized to study the workers performance and its importance for the improvement of work and the worker. All forestry operations in Pakistan are carried out with traditional methods and tools, resulting in to a very low labour productivity reflected by a poor socio-economic conditions of forest workers.

This study is the first of its kind in the country and its results revealed that at an average the technical labour productivity in timber harvesting in Pakistan is 0.27 m^3 (timber + firewood) per man hour. The tree species worked were mulberry (Morus alba) and shisham (Dalbergia sissoo) in the irrigated forest plantation of Changa Manga. The average DBH of trees was 27 cm and the work consisted of felling, debranching, firewood conversion and cross-cutting, but no debarking. The above technical labour productivity figure is an average for improved tools ($0.31 \text{ m}^3/\text{man hour}$) and conventional tools ($0.25 \text{ m}^3/\text{man hour}$).

These figures of labour productivity from Pakistan are very low as compared to the labour productivity figures from the developed countries. Taking the example of Federal Republic of Germany, the technical labour productivity in the Bavarian State Forests during 1984 was $1.65 \text{ m}^3/\text{man hour}$ (ANONYMOUS, 1984 a).

This is an overall average for different species and tree sizes and the work includes felling, debranching, cross-cutting and debarking, but no firewood conversion.

The technical labour productivity in the Federal Republic of Germany is more than six times higher as compared to technical labour productivity in forest plantation of Changa Manga in

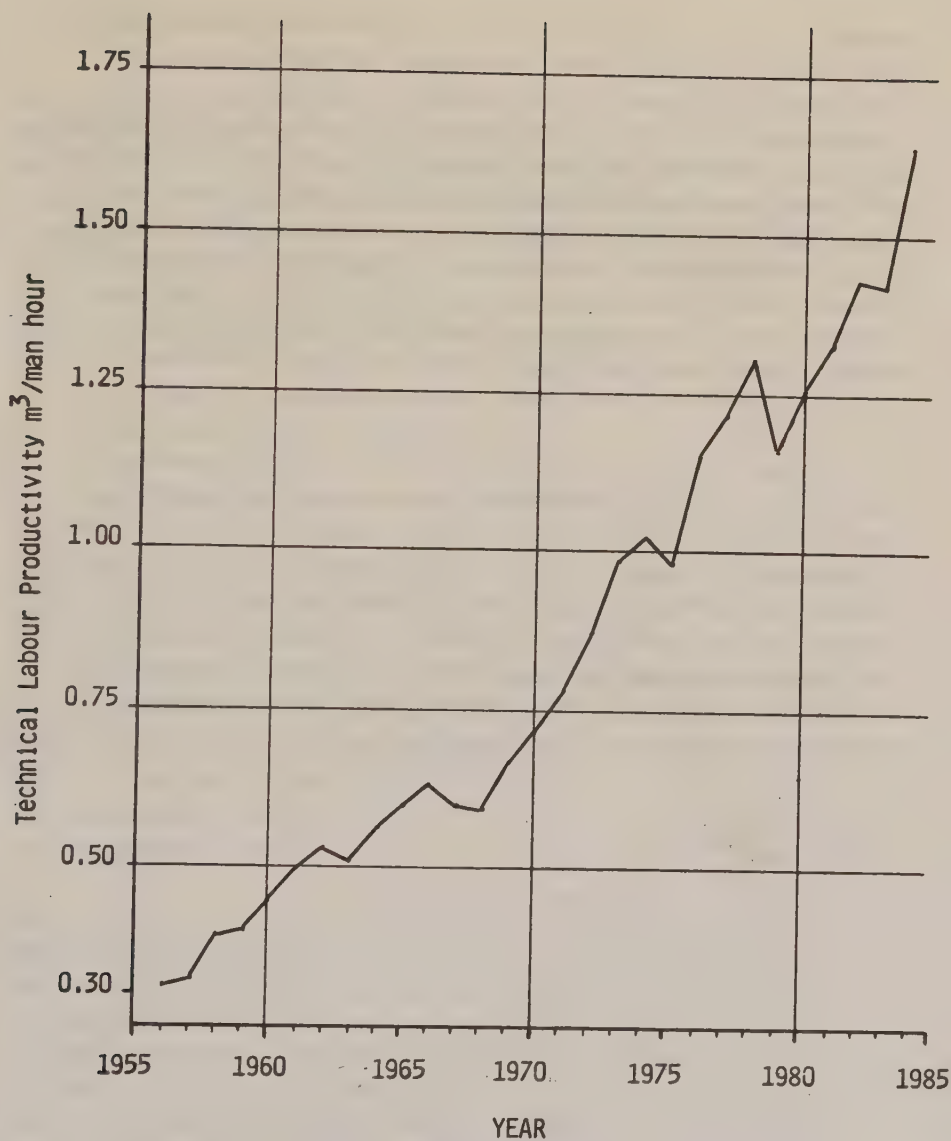


Fig.4: Development of technical labour productivity in timber harvesting in the Bavarian State Forests from 1956 to 1984

Pakistan. This big difference is no doubt mainly because of a high state of technological development in Germany.

Even more interesting is the sequence of development of technical labour productivity from 1956 to 1984 (Fig. 4). In 1956 the technical labour productivity in Bavarian State Forests was $0.31 \text{ m}^3/\text{man hour}$, predominantly with hand tools. This level is exactly comparable to the technical labour productivity with improved tools in Changa Manga Forest Plantation in Pakistan during 1984-85. But technical labour productivity in timber harvesting in Bavarian Forestry showed a sharp and steady increase of more than five times over a period of 28 years.

This dramatic increase was possible due to the replacement of hand tools with power chainsaws, more emphasis on workers training and mechanization. Moreover, well opened-up forests, efficient means of timber extraction and transportation has also changed the work outlook. Instead of assortments, the trees are now mostly harvested as a whole or in full lengths. This new system of mechanized tree harvesting caused a manifold increase in technical labour productivity in the Federal Republic of Germany as well as in other industrial countries.

3 WORKLOAD

Workload or stress can be defined as mental, emotional and physiological effects of work on human body and are known as mental, emotional and physical workloads respectively. Because of the same organ of response (human brain), mostly occurring simultaneously and almost similar indicators, the mental and emotional workloads will be discussed together in this chapter, while the physical workload connected with the effects of muscular activity on the physiological functions, will be dealt with separately.

3.1 MENTAL AND EMOTIONAL WORKLOAD

3.1.1 Definition

Mental and emotional workload can occur in different professional activities and is a special feature of modern life. Mental and emotional stress is particularly common to the professions involving supervision, checking and manoeuvring responsibilities. Mental workload is characterized by effect free information processing, while emotional workload can be due to different activities with sensation based negative effects such as anger, fear and time pressure (RUTENFRANZ and KLIMMER, 1976, cited by ROHMERT and RUTENFRANZ, 1983).

Mental workload pertains to the sensory activities in which informations are received through sense organs, such as in discriminate activities of quality control, where goods are examined for their strict conformity to the quality standards. In combination activities like air traffic control, mental workload results through the activities of central decision making mechanism to give decisions in a definite time and also when the number of decision processes in relation to the processing capabilities of individuals are very high (ROHMERT and

RUTENFRANZ, 1983) as well as in **signaling** or **signal motor activities** in which work results are carried over by an information process through expression reactions, such as mimicry, gestic or speech or such activities in which motor reactions are necessary (operating of controls, switching or pressing of keys).

Increased mental and emotional stress may lead to the overloading of central nervous systems, resulting into the manifestation of numerous psychosomatic diseases (EIDE, 1971) like stomach ache, bronchial asthma, essential hypertension, insomnia, cardiac diseases and behavioural disturbances.

3.1.2 Measurement of Mental and Emotional Workload

For recording of mental and emotional stress there are many estimates and most of them are the evidence of actual or experienced strain (ROHMERT and RUTENFRANZ, 1983) by the persons. These methods involve the recording of changes in psychological, physical and bio-chemical processes. But none of them provides a well functioning parameter (ZANDER, 1984, FIBIGER, 1980) for the estimation of mental and emotional stress.

3.1.2.1 Psychological Methods

With psychological methods one can differentiate between an objective and subjective assessment of strain. With objective assessment the level of strain due to definite activities is judged.

a) **External observations:**

The activity carried out is to be classified quantitatively and qualitatively by another person who is well familiar with the workplace.

b) Performance Studies:

In this method the test results (calculation test, reaction test, association test and discrimination test) before and after the activity carried out are studied (STRAUB, 1968, cited by ROHMERT and RUTENFRANZ, 1983) and compared. The difference in the fore and after measurements as misses and mistakes are considered as indicators of strain during the activity carried out.

c) Carrying out of a Second or Side Activity:

Here one understands that the percentage proportion of performance for the two activities carried out at the same time is always the same. The less performance of second activity can be connected to the higher performance of first activity (HACKER and RICHTER, 1980, cited by ROHMERT and RUTENFRANZ, 1983). The type and extent of interference in the information processing related to first and second activity gives a valid estimate of strain (WICKENS, 1979, cited by ROHMERT and RUTENFRANZ, 1983). The difficulties of laborious analysis is a feature of this procedure as with many other psychological methods.

3.1.2.2 Physiological Methods

For the assessment of mental and emotional stress **physiological indicators** can also be used. For all such type of indicators, it is needed that they are not specific to the activity tested and adverse effects of physiological measurement on the activity performed should be as low as possible to exclude the possible interference. There are many physiological estimates of mental and emotional stress, but only the important ones will be taken in this discussion.

a) Heart Rate:

The measurement of heart rate as well as its irregularities is the best indicator of mental and emotional stress among all the known practical methods (ROHMERT and RUTENFRANZ, 1983). Since the turn of the century, recovery heart-rate gave informations for the simple activities. But it should also be borne in mind that the changes in heart rate can cross the normal limits only when the mental and emotional stress is very high and in such critical situation heart rate shows a sudden and short lasting rise often associated with a similar fall. These quickly occurring changes, naturally become indistinguishable (ROHMERT and RUTENFRANZ, 1983) from the mean heart rate over longer periods of time.

b) Sinus Arrhythmia:

Sinus arrhythmia is defined as "fluctuations in vogal tone and heart rate; speed up of the heart rate during inspiration and slowing down during expiration" (NORTH et al., 1982). In mental and emotional stress there occures the suppression of sinus arrhythmia, that means the heart rate remains more or less uniform over a breathing cycle.

c) Endocrine Studies:

It has been known that under physical and mental stress situations the secretion of hormones like catacholamines from adrenal medulla and corticosteriods from adrenal cortex is greatly increased (EIDE, 1971). The quantities of these hormones can be determined by the analysis of urine and blood samples. In practice the former method of testing the urine is more preferred. In such studies the total urine output of the subject is measured over 3 intervals of 90 minutes each, presenting a pre-stress, stress and post-stress periods (ROHMERT and RUTENFRANZ, 1983, EIDE, 1971). These samples are analysed for their hormonal concentration. The hormonal secretion during pre- and post-stress periods is used as control to overcome the diurnal variations in hormone secretion. The intake of

liquids and use of stimulants like tobacco, coffee and alcohol are to be controlled during the course of experiment.

d) Galvanic Skin Reaction (GSR):

The electrical resistance of skin changes with the activity of sympathetic nervous system (EIDE, 1979). In increased mental and emotional stress situations the sweat glands in the skin are activated and electrical resistance of the skin falls. Silver chloride electrodes are used for this purpose, placed each on the palm and back side of the hand. A number of recordings are to be made at the same time. Interindividual differences are very high and each individual has got a specific pattern of response.

The other physiological methods for the assessment of mental and emotional stress are blood pressure, breathing frequency, eye-lids movement and electro-encephalography (EEG).

3.2 PHYSICAL WORKLOAD

3.2.1 Definition

In the most simplest words the physical workload can be defined as the physiological effects of muscular work on human body producing great physical exertion. The workload may be static or dynamic depending upon the nature of work.

The work in which the body muscles remain only under one type of strain, either stretched or contracted and no or least physical movement is involved, produce **static workload** and in those activities in which the movements are rhythmic and muscles contract and relax alternatively produce **dynamic workload**. Static workload is more tiresome than dynamic workload (KAMINSKY, 1971). In static work, blood and food supply to the muscles and removal of waste products from the muscles is restricted (Fig. 5), therefore,

the muscles are fatigued earlier (CHRISTENSEN, 1964, GRANDJEAN, 1981). While in dynamic physical work, the blood and food supply to the muscles and removal of waste products from the muscles is rather improved, therefore the muscles can work longer.

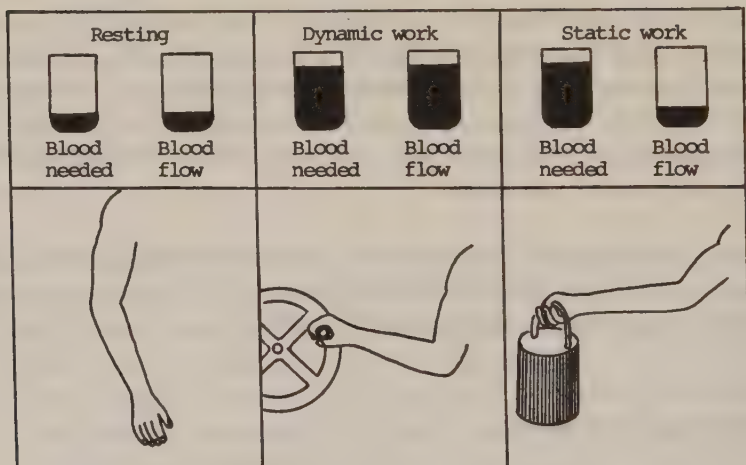


Fig.5: Diagram of dynamic and static muscular work

(After Grandjean, 1981)

Every physical work whether light or heavy produces a workload, but it is only worth attention when it exceeds its safe limits. High and constant physical workload means increased strain on musculo-skeletal system, cardio-vascular system and body energy reserves, with the following consequences:

- early fatigue,
- reduced work hours,
- early retirement,
- body complaints.

The studies are emphasised in forestry work that how often and how long the physical workload exceeds beyond the tolerable limits and the results can be used for (ZENDER, 1979):

- the comparison of tools,
- the comparison of work methods,
- the design of work places,
- the calculation of rest allowances.

3.2.2 Measurement of Physical workload

There is no direct and single determinant of physical workload. Study of any of the physiological parameters taking part in the activity of work can be considered as indicators of physical workload.

For work the human body needs two basic materials i.e., food and oxygen. The food is decomposed within the human body through oxidation (GRANDJEAN, 1981) and energy is released to the muscles for the work and heat as by-product of the reaction (Fig. 6). The quantities of these reacting substances (food + oxygen) and reaction products (energy + heat) proportionately increase with the increasing physical activity and hence with physical workload (CHRISTENSEN, 1964). Measurements of any of these reactants or reaction products can be considered as a useful determinant of physical workload, such as oxygen consumption at work as lO_2/min or through the increased activity of its transport system (cardio-vascular system) in the form of higher heart rate, energy expenditure as kilocalories (kilojoules) per minute and body temperature.

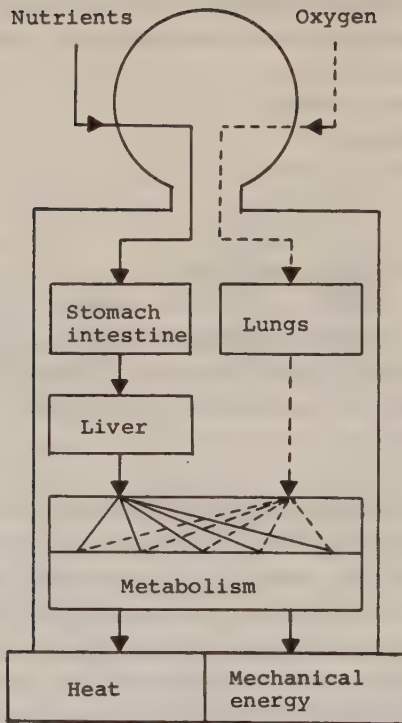


Fig. 6: Diagram showing the conversion of nutrients into heat and mechanical energy in the human body

(After Grandjean, 1981)

3.2.2.1 Blood Circulation and Oxygen Transport

One litre of blood can transport 200 ml of oxygen from lungs to the body (ANON., 1961, KAMINSKY, 1980), bound by the haemoglobin contained in the blood. The body uses only 40 % of this oxygen while at resting state. The heart works as pumping mechanism for the blood and has a sharp correlation with quantity of oxygen needed by the body. When the need for oxygen increases because of muscular work, the heart transports more oxygen carried through the agency of blood to the muscles and therefore, it beats quickly. The heart rate taken as number of beats/min is a useful indicator of oxygen transported and physical workload.

3.2.2.2 Heart Rate

Continuous heart rate monitoring is the simplest and most practical mean of measuring physical workload at work under field conditions. The use of heart rate as a criterion of physical workload has several advantages. Mostly a simple instrument like a stop-watch can be used. It gives immediate information and conclusions can be drawn over longer times without much interfering the work. Relatively trustworthy equipment is also available, with which heart rate can be recorded continuously over long intervals (CHRISTENSEN, 1964). Moreover, the heart rate may be used as such (LOON, 1984), as a simple parameter of physical workload, which is particularly useful in comparative studies. While most of the other methods, such as uptake of oxygen, energy expenditure and body temperature measurements involve sophisticated instrumentation and also mostly spot studies are only possible.

Heart rate, although being simplest of all the other methods is also open to many objections, because not only the heaviness of the work, but many other factors affect the heart rate. For example, disease, smoking, climate, training (TEIKARE, 1981),

age (CHRISTENSEN, 1964, MELLEROWICZ and SMODLAKA, 1981), working posture (LOON, 1984) and individual variations. For the use of heart rate as a measure of physical workload, the heart rate of workers in the state of rest should be taken down each day before the start of work. This is known as **resting heart rate** and serves as a base value for the calculation of average and maximum working pulse. HETTINGER and NESPER-KLUMP (1981) could reduce the inter-individual variations of heart rate by about 58 % by choosing a sub-maximal pulse as a base value for the observed total pulse. Heart rate and pulse are synonymous terms and have indiscriminately been used in the following chapters.

Methods of Heart Rate Measurement

a) Manual Method

There are different methods for the study of heart rate. The most simplest is the manual method by feeling the pulsation of radial artery in the wrist (GRANDJEAN, 1981) or at the carotid artery near Adams apple (LOON, 1984, ANDERSON, 1971) by the fingers of the hand. The observations on heart rate are recorded systematically in a manner of multimoment with a fixed observation interval and with respect to different work elements being performed. At the observation point, the person who is taking the pulse approaches the worker quickly, makes a sound signal so that the worker stops working (but maintaining the work posture), immediately puts his right hand fingers on the radial artery in the wrist or on the carotid artery near Adams apple of the worker and takes down the time of 11 pulse beats or 10 intervals (MELLEROWICZ and SMODLAKA, 1981, LOON, 1984) with the help of a stop-watch. The method is very easy and even the beginners can master the art with a little practice. The heart rate as No. of pulse beats/min can very easily be calculated by using 600 as numerator and time of 11 beats in seconds as denominator or can be read against the time from the tables. Special calibrated stop-watches (Fig. 7) are also available which directly give the number of beats/min.

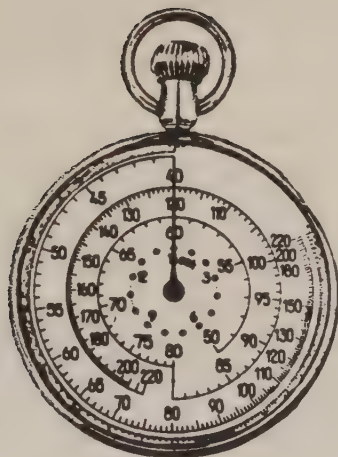


Fig.7: Special stop-watch for pulse counting

(Hansson et al., 1966)

The manual method of heart rate measurement is subject to the following criticism:

- The worker has to stop working, by which his heart rate quickly falls down and the measured values are always lower than the actual heart rate for that operation.
- While taking the time of 11 beats, which may normally range between 3.5 to 6.0 seconds in forest work, the heart rate slows down constantly and the measured value is not the heart rate when the pulse was felt for the first time but an average over this period.
- The method is somewhat laborious for the observer and disturbing for the worker as well.

- The accuracy of this method also depends upon the vigilance and practice of the person who is taking the pulse. The more quickly he extends his hand, puts his fingers on the desired region and feels the pulse, the more accurate will be the results.
- The difference in the perception of start of counting and end of counting of pulse is another source of error. If two persons observe the pulse of a worker at the same moment by manual means, their results are rarely comparable with each other. The error increases with increasing heart rate (MELLEROWICZ and SMODLAKA, 1981) and varies from 0.5 to 3.0 for a heart rate of 60 to 180. Anyhow this error is compensating and if the same operation is being observed for enough time, the average is fairly correct. ANONYMOUS (1981) observed a difference of 10 beats when comparing the accuracy of manual method of pulse measurement with photo-electric cell.
- Another aspect of manual measurement of heart rate is the long observation intervals of several minutes (6 to 10 min, ANONYMOUS, 1961), which cannot be reduced in view of much disturbance to the worker and frequent interruption of work. In this experiment an observation interval of 3 minutes is used, which the author believes to be the minimum.

Special Precautions in Manual Measurement Heart Rate:

- When a worker is doing a very light job, the feeling of pulse at radial artery in the wrist is very prominent, but in heavy work the pulse beats are so quick that they are difficult to feel. The reverse is true for feeling the pulse at carotid region. So in heavy work heart rate measurement at the carotid artery should always be relied upon.
- Some workers have got the habit of swallowing the saliva when their Adams apple is touched and one misses the beats. In such cases the worker should be warned in advance to refrain from doing so.

In spite of its many short-comings, the manual method of heart rate measurement is still a useful tool for ergonomic research in developing countries, which cannot afford expensive equipment because of lack of capital.

b) Pulse Meters

The second method for heart rate measurement is with the help of pulse meters. These are small instruments of the size of a pocket calculator. Based upon their principle of working these instrument fall into two main types. One type is built on the principle of photo-electric cell. While in the other type of pulse meter, the changes in the electric potential of contracting heart muscles are recorded by the electrodes attached to the chest of the worker.

In both cases heart rate can be read directly from the display screen. These meters can be attached to the back of the worker, held in hand on a time study board with the help of lengthening cable.

The use of photo-electric cell for monitoring the heart rate at work is recommended by E. A. Müller, 1957 (cited by ANONYMOUS, 1961, KAMINSKY, 1980). A device using this principle will be described in detail under "The Kettler Pulse + Time Meter", in chapter 3.2.2.3.

c) Telemetry

The last and the most sophisticated method is the telemetry, which gives a continuous and complete record of heart rate. A telemetric set consists of a transmitter attached to the worker and a receiving set placed at a distances. Electrodes of the transmitter are attached to the chest of the worker. They record the changes in the electric potential of the contracting heart muscles of the worker and transmit the signals to the receiver. There these mes-

sages are analysed by a computer and recorded either as electrocardiogram, cardio-tachogram or printed out as digits with frequency of breathing and time study details (WENZL, 1983) or even can be stored on the magnetic disc or tape. Elements of a work are numbered and the time keeper has got in his hand a subject marker by which he can tell the receiver what type of activity is being performed by the worker. In some models the transmitter is replaced by a bioport pocket, which digitally stores the heart rate data instead of transmitting. At the end of day the informations are transferred to a computer for storage and analysis.

The biggest drawback in the application of telemetry for the study of heart rate during work is very high cost of the telemetric equipment and need of trained persons. The cost is further increased when the heart rate of more than one worker is to be recorded, because one bioport pocket and one subject marker is needed for each worker.

Limits of Heart Rate

According to E. A. MÜLLER (cited by GRANDJEAN, 1981) the limit of continuous performance for men is reached when the average working pulse is 30 beats/min above the resting pulse, both of these measured in the same posture. When the resting pulse is taken in seated position then the increase of 35 work pulses (GRANDJEAN, 1981) should be taken as a limit for continuous performance. In general the heart rate of a worker at work should not exceed 30 - 35 beats above his resting heart rate over longer periods of time. The upper limit of balance is an average heart rate of approximately 110 beats/min (LOON, 1984).

CHRISTENSEN (1964) characterizes the work on the basis of heart-rate into following categories:

Physiological variable	Physiological Workload				
	Light	Moderately heavy	Heavy	Very heavy	Extremely heavy
Heart Rate No. of beats/min	75-100	100-125	125-150	150-175	> 175

3.2.2.3 The Kettler Pulse + Time Meter

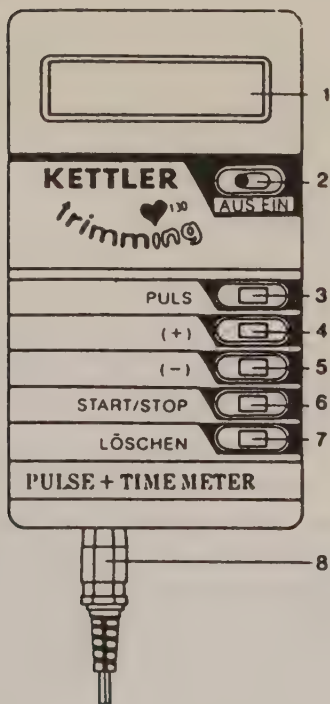
Working principle and constructional details

A light source as a small electric bulb and a photo-electric sensor are built in the form of an ear-clip, in such a way that the light source and sensor oppose each other. When this ear clip is attached to the ear lobe of the worker and the instrument is switched on, the tiny bulb in the ear clip starts glowing and light passing through the ear lobe is received by the photo-electric cell (sensor). The blood circulation in the ear lobe corresponding to the beating of heart cause changes in the light intensity passing through it. These light intensity variations are sensed by the photo-electric cell on the opposite side as electric pulses, which are led via a lead to a mini-processor built in the body of meter. This mini-processor converts the time interval between two electric pulses into the number of heart beats/min, which is digitally displayed on a small screen.

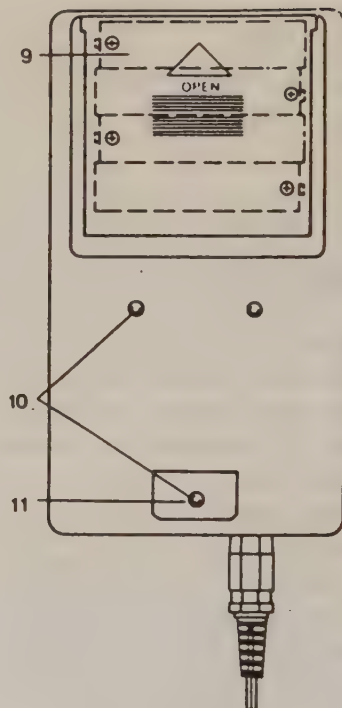
Fig. 8, shows the constructional details of Kettler Pulse + Time Meter, both in front and rear views. Keys at No. 4 and 5 denoted with (+) and (-) are used for fixing the limits of pulse, needed in physical tolerance exercise and an acoustic signal appears when the desired level of heart rate is approached. These keys are of no interest in this discussion. The reset key No. 7 is

Fig.8: Details of Kettler Pulse + Time Meter

Front View



Rear View



1. Display
2. On/Off switch
3. Pulse key
4. (+) key
5. (-) key
6. Start/stop key

7. Reset key
8. Plug for signal input
9. Battery cover
10. Mounting holes for large bracket
11. Mounting point for belt fixture

used for resetting the instrument in case the error signal "E" appears on the display No. 1. At No. 8 is the plug of lead from ear-clip fitted into the socket of pulse meter. Mounting holes for bracket for fixing the meter to the belt and on the normal or ergonomic bicycle are shown by No. 10 and 11.

There are two possibilities of using this instrument. One is by attaching the pulse meter to the back of the worker with the help of a wire clip fixed to the holes No. 10 and 11 (Fig. 8) on the rear side of the meter and safety pins. In the other method the instrument is fixed on a time study board and the sensor is attached to the ear lobe of the worker with the help of an extension cable. The former method was found unsuitable in tree felling and conversion work, because of difficulty of reading the digital display due to quick movement and bending down of workers, while felling the trees with axe. So the latter method of fixing the instrument on the time study board was used in this experiment.

Each pulse meter was fixed to the left hand corner of the time study board with the help of small size ring bolts and elastic rubber band. These instruments work with 6 V current provided by four 1.5 V micro batteries. Micro batteries are more expensive and normally are difficult to procure in a country like Pakistan. Therefore, the each instrument was made to run with the help of 4 mignon batteries, arranged in a pack outside and connected to the meter with the help of wires. An additional pack of 4 batteries was also kept as stand by. This arrangement not only made the working of meters cheaper, but also assured the continuous working by quick change over from consumed batteries to the stand by pack by simply changing the connections. While in case of micro batteries placed inside the meter, replacement of old batteries was only possible by opening the instrument and discontinuing the work. During the course of experiment it was found that a pack of new batteries runs only for about 8 hours of continuous work.

Precautions for the use of pulse meters with extension cables:

- While detaching the extension cable from pulse meter or lead of the ear clip, do not simply disconnect by pulling the cables apart, but always hold them from plug and socket, otherwise, there is a great risk of breaking of delicate connections inside the plug and socket.
- The extension cable at one end should firmly be supported to the time study board and at the other end to a belt tied to the waist of the worker. This is necessary to avoid the risk of loosening and slipping out of connections during movement.
- When the distance between the worker and time keeper is less, the surplus length of the extension cable falls down to the ground and there is a great risk of getting entangled with the shrubs and brush wood. To cover this risk the free length of the cable should always be rolled up in the left hand of the time keeper. Another advantage of doing so is that when the time keeper is not in a position to move immediately with the worker, he simply lets loose the rolled up cable and then finds enough time to adjust his position. It is advisable to keep a portion of extension cable always rolled up in hand as a safety measure against jerks and slipping out of connections because of untimely movement of the worker and the time keeper.

Switch the meter on by setting the red button (No. 2, Fig. 8) to "ein", the digital display will register "0" for the time and pulse with an acoustic signal. If there appears no digit on the display, check the batteries and their arrangement. By pressing the start button (6) stop watch function will start. Push the plug of the ear clip lead (8) or of extension cable into the socket of pulse meter. A small bulb in the ear clip will start glowing. If the bulb fails to glow, check for the proper fitting of plugs into the sockets.

Broken wire connections in the socket and plug of extension cable can also be a cause of dead bulb in the ear clip. If this is suspected, broken connections may be located and repaired.

Attach the ear clip to the ear lobe of the worker, with the light source behind the ear lobe. Ear clip should also be supported with the ear of the worker by means of plastic clip. Surplus ear clip lead should be coiled up and fixed to the clothes of worker to avoid swinging during work, but with enough allowance for free movements of body and head. Press the pulse button (No. 3, Fig. 8), a "heart shaped" sign for pulse and "HI" sign for time will appear on the display with an acoustic signal.

The workers may be asked to start the activity of work and the observation on heart rate with the help of pulse meter be recorded systematically in a manner of multimoment with a fixed observation interval and entered on the proformas (Fig. 9) with respect to different work elements. The study will be a combined one, both for heart rate and time, because the number of heart rate entries will also give the number of points for multimoment.

In an attempt to monitor the heart rate of forest workers during tree felling and conversion the author used Kettler Pulse + Time Meters. The results of this experiment are as follows:

Results

The heart rate data recorded with photo-electric cell (Fig. 9) gave amazing results. It is a well known fact that in the work of timber harvesting, tree felling is the most strenuous job and heart rate in this activity remains far higher than the operations like preparation, operational delay and measuring etc. But the collected data is just opposite of it. Average heart rate figure of 64 in felling and the lowest value of 44 are ridiculous figures, while average heart rate for easier works like preparation and operational delay remained 110 and 86 beats/min, respectively.

Fig. 9: Heart Rate Measurements with Photo-electric Cell
(Pulse Meter)

Study Level I Worker No. 3 Temperature 36°C Wind N/E
Forest Division Kasar (Changa Manga) Date 30.9.84 Cloudiness Clear Recorded by A. Salam
Forest/Compdt. No. 157 Time Interval 1 min. Rain N/E

Tree Parameters	Work Elements and Heart Rate										Average Heart Rate for cycle
	Prep.	Oper. Delay	Person Delay	Walk	Felling	Hammering	Debranching	Firewood Conversion	Measuring	Cross-cutting	N.A
1	2	3	4	5	6	7	8	9	10	11	12
Tree No. 104 Species: <i>Shisham</i> DBH = 60 cm	110	95	65	98	82		102	102/103	70	59	68
		86	67	98	70		70	100/93	63	75	91
		70	61	93	32		69	89/73	92	115	65
		89	77	89	73		58	70/78	89	58	74
		106	81	91	85		60	58/81	80	58	74
		102	94	77	55		73	73/79		63	71
		96	84	84	46			70/96		63	52
		104	89	92	45			68/111		67	57
		101	103	105	44			67/99		67	73
		58	72	77				81/80		65	75
		105	103	92				66/85		80	75
		57	61	94				83/50		83	50
		62	57	93				82/97		87	61
		70	84	83				66/77		67	60
			67	87				63/71		71	67
Heart Rate in a work element-wise	Σ P	110	1209	3902	572		432	2737	399	7515	16876
	Mean	(110)	(86)	(81)	(64)		(72)	(81)	(89)	(73)	(87)
	Max./Min.		106/57	105/55	84/44		102/58	110/58	97/63	115/52	115/44

This was enough to doubt the dependable working of these instruments. So these instruments were compared with the other methods of heart rate measurement for checking their accuracy.

From 22nd October to 16th November 1984, the author happened to visit the "International Agriculture Centre", Wageningen, The Netherlands to attend a training course in ergonomics. There the opportunities were availed for testing the functioning of pulse meter (photo-electric cell) against telemetric set with the kind assistance of Dr. J. H. VAN LOON, Section of Occupational Health and Ergonomics, Agriculture University of Wageningen. Pulse meter and telemetry transmitter were attached to the author himself at the same time and pulse was read by Dr. VAN LOON from the pulse meter and digital print out by the computer of telemetric set with an observation interval of 15 sec. Activities performed were sitting in the chair, going with about 5 kg of load and going with load and bending down.

Twenty heart rate observations were recorded for each type of activity for both of the heart rate measurement methods.

The results of this comparison are given in the table 6, which showed that the pulse meter at the average measured the heart rate always less than the telemetry by 9, 11 and 14 beats/min. for sitting, going with about 5 kg load and going with load and bending. The difference went on increasing with the work involving more and more body and head movement.

Table 6: Comparison of heart rate measurements with photo-electric cell and telemetry

Activities Performed	Average Pulse/min		Difference
	Pulse Meter	telemetry	
1. Sitting	87	96	9
2. Going with about 5 kg load	87	98	11
3. Going and bending with about 5 kg load	91	105	14

No parallel comparison of photo-electric cell and manual method of heart rate measurement could be carried out. Only the results of heart rate recored by the two methods (Fig. 9 and 10) at different occasions are compared. In table 7 the average total heart rate vaules measured by means of photo-electric cell and manually during felling and conversion of two mulberry trees of comparable DBH (33 cm) and with a work party size of same three workers are given.

Fig. 10: Manual Measurement of Heart Rate

Tree No.	No. of Observations	Level of Study				Forest Division				Date				Temperature				Wind				Recorded by
		Kasur, Changa				4.2.85				23°C				MIL								
		Forest/Comptt. No. Mangla 12				Time Interval 3 min				Cloudiness				Rain				MIL				
1	2	Prep.	3	4	5	6	7	8	9	10	11	12	13									
		T	P	T	P	T	P	T	P	T	P	T	P									
194	1																					
Species																						
Mulberry																						
DBH cm																						
35																						
	Σ P				272		147		134		342		511									
	Mean				(91)		(147)		(134)		(114)		(228)									
	Max/Min				107/90						120/103		132/120									
	3																					
					5.79/104		4.69		5.37/144		173/124		4.15									
					5.95/101				5.66/145		119/124		4.99									
					5.96/101				5.29		113											
	Σ P				306		128				593		244									
	Mean				(102)		(128)				(119)		(122)									
	Max/Min				104/101						124/113		124/120									
	4																					
					6.51/95		3.64		5.26/107		114/99											
									5.27/106		114/119											
									6.11/106		98/119											
									4.74/146		127/130											
	Σ P				95		161				920											
	Mean				(95)		(161)				(115)											
	Max/Min										130/98											
	Heart Rate in a Work Cycle				673		442		134		1855		755									
	Mean				(96)		(147)		(134)		(116)		(126)									
	Max/Min				107/90		167/128				130/98		132/120									
	Heart Rate in a Work Cycle																					
	Mean																					
	Max/Min																					
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	Heart Rate in a Work Cycle																					
	Mean																					
	Max/Min																					

Table 7: Comparison of average total heart rate values measured by photo-electric cell (Kettler Pulse + Time Meter) and manually in tree felling and conversion

Work Elements	Av. Heart Rate		Difference
	Photo-electric cell	Manual	
1. Preparation	-	-	-
2. Operational Delay	-	-	-
3. Personal Delay	92	96	4
4. Walk	88	-	-
5. Felling	71	147	76
6. Hang-up	87	-	-
7. Debranching	74	134	60
8. Firewood conversion	68	116	48
9. Measuring	-	-	-
10. Cross-cutting	84	126	42
Av. for the work cycle	83	117	34

The observation interval for photo-electric cell and manual method remained 1 minute and 3 minutes respectively. The average total heart rate for the work cycle as measured by photo-electric cell remained by about 34 pulse beats less than the manual method. The minimum difference of 4 pulse beats was for personal delay, while the maximum of 76 was for felling. The difference seems to increase proportionally with the heaviness of work elements involving more and more body and head movements.

Probable causes for errors in photo-electric cell (Kettler Pulse + Time Meter) when used in tree felling and conversion work might be:

- Heavy work means heavy muscular activity and heavy movement of head. Movement of head means jerks to the earclip and lead which cause relative movement of ear lobe and ear clip and can induce false electric pulses from sensor to the processor. Working muscles generate electric potential proportionately to the work, which can interfere with the functioning of photo-electric cell.
- Movement of lead and extension cable probably causes relative slipping of thin copper wires inside the cable against each other and cause interferences in the passing signals.
- The instruments were used with about 5 meters of extension cable. This length of the cable might have offered much resistance to very weak electrical signals passing through it and have further reduced the strength of these pulses.
- The instrument gives best results if the ear clip is placed at a higher position on the ear lobe. If positioned near to the lower edge of the ear lobe the instrument may give wrong results probably because of restricted blood circulation in this region which is further reduced by the pressure of ear clip.
- As common to almost all electronic equipment very low and very high temperatures can also cause errors in the display of the instrument.
- Sun light and flickering light also causes interference in the working of the instrument. When the instrument is not protected from the direct and strong sunlight will give wrong figures and this is particularly important when the instrument is used in forestry operations like tree felling and conversion.

- Weak batteries provide weak current which caused wrong displays, indicated by the absence of heart shaped sign on the display. Batteries should be replaced after 4 - 6 hours of continuous work.

Conclusions

If the probable causes of error in the use of photo-electric cell (Kettler Pulse + Time Meter) for monitoring of heart rate of workers are kept in mind and instruction manuals provided with the instruments is thoroughly read and followed, these instruments can be used for monitoring the heart rate of workers doing very light and sedentary jobs.

3.2.2.4 Oxygen Consumption

The quantity of oxygen absorbed by a worker at work is directly related to the increase in energy release through the increased oxidation of food material with increasing physical workload. Therefore, oxygen consumption at work measured in litres/min is also taken as an important criterion of physical workload. For the estimation of oxygen consumption the expired air during work is either collected in Douglas Bag or respirometer tank (ANDERSEN, 1971) or directly led through the respirometer (VIK, 1971) developed by the Max Planck Institute of work physiology. The collected air in Douglas bag or respirometer tank is also latter on metered by the respirometer. The worker under test breaths through a two-way expiratory valve (Fig. 11), which is connected to the respirometer or collecting bags with the help of a rubber tube. A small sample of this air is also collected in a rubber bladder for the determination of its oxygen contents, with the help of Pauling paramagnetic oxygen analyser. The expired air is corrected for temperature, pressure and humidity. The duration of test is also noted down in minutes and from this the rate of expired air in litres/min is calculated. There exists a linear relation-

ship between oxygen uptake and work output (Fig. 12). The oxygen contents of expired air are used for the calculation of the quantity of oxygen in litres/min consumed by the worker.

The oxygen uptake as a measure of physical workload is judged against the maximal aerobic power of the worker. The maximal oxygen uptake or the maximal aerobic power ($V_{O_2\text{-max.}}$) of a worker is the maximum quantity of oxygen, which he can absorb through breathing at the maximum rhythmic workload and is expressed as litres of oxygen/min or ml of oxygen/min/kg of body weight (EDHOLM, 1979) or more sophisticated as ml/min/kg of lean body mass. Lean body mass is fat free body weight.

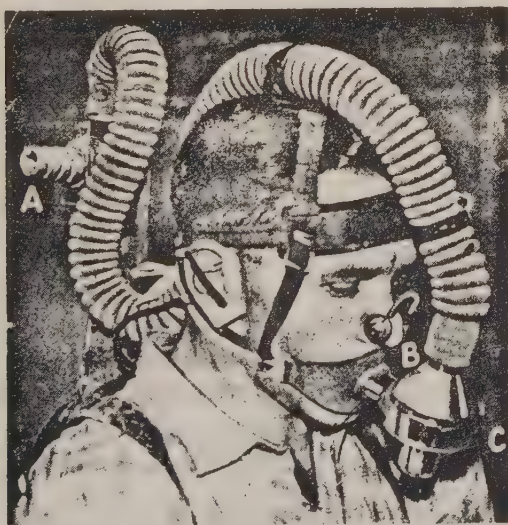


Fig. 11: Measurement of energy needs with "Douglas-bag" method (Anonymous, 1961)

- A- Air tight connection
- B- Nose clip
- C- Breathing valve with rubber mouth-piece

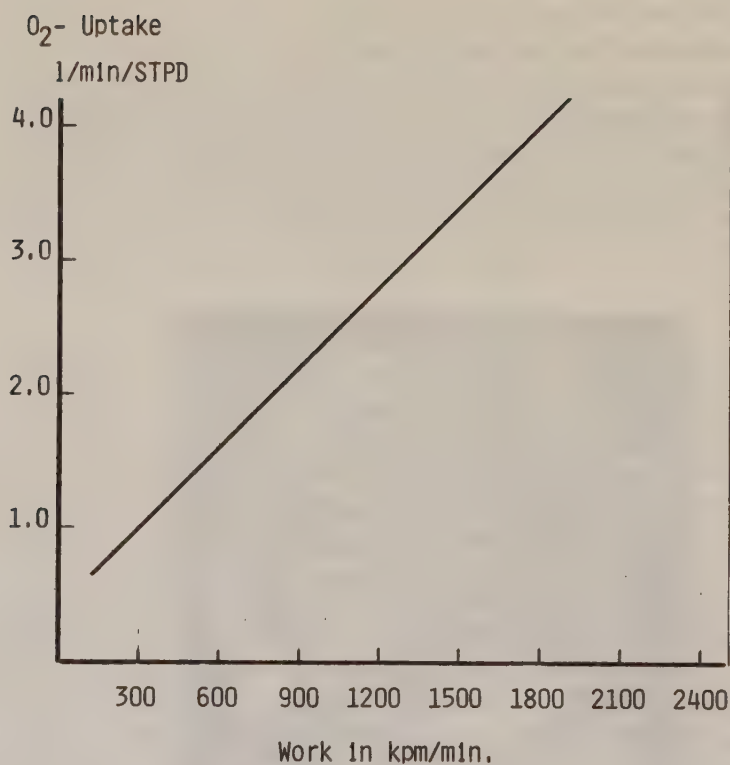


Fig.12:Oxygen uptake in relation to work output
on a bicycle ergometer (Anderson, 1971)

CHRISTENSEN (1964) defines a standard worker as a man of 20 - 30 years of age with a maximal aerobic power of 4 litres of oxygen/min. He also characterises the work based upon the uptake of oxygen into the following categories:

Physiological variables	Physiological Workload					
	Very Light	Light	Moderately Heavy	Heavy	very Heavy	Extremely Heavy
Oxygen Uptake l_{O_2}/min	0.5	0.5-1.0	1.0-1.5	1.5-2.0	2.0-2.5	2.5

The limit of continuous performance for a worker is an oxygen uptake of about 40 % of his maximal aerobic power.

3.2.2.5 Energy Expenditure

The determination of calories expenditure is one of the most useful tools (CHRISTENSEN, 1964) in quantitative and objective job evaluation not only in the laboratory but also under field conditions. It is not only the heaviness of work but climate and body size of the worker which also affects the energy expenditure. Calorific demands of bulky workers under cold climates is more than the light statured workers working in hot climates, because they present a light working machine and reduced daily work hours due to long and frequent breaks necessitated by inefficient heat exchange in high temperature and humidity.

Different authors reported different energy demands for the whole day and 8 hours of forest work under different situations. A forest worker in Sweden consumes close to or even more than

5,000 kcal (21,000 kJ) per day (CHRISTENSEN, 1964) and 4,500 - 5,500 kcal (18,000 - 23,000 kJ) during peak seasons under German conditions (WIRTH, 1971) per 24 hours. Out of these about 4,000 kcal (16,700 kJ) per 8 hours or 8.3 kcal (35 kJ) per minute are used as work calories. LEYENDECKER (1953) estimated for German forest workers, engaged in timber harvesting an energy need of 2,520 kcal (10,500 kJ) per 8 hours and 5.25 kcal (24 kJ) per minute as work calories. KAMINSKY (1960) gives the total energy requirements of a forest worker as 4,800 kcal (20,000 kJ) per day, out of which 1,700 kcal (7,100 kJ) are for basic needs for maintaining of body temperature and for functioning of different organs, 600 kcal (2,500 kJ) for free time and recreation and 2,000 kcal (8,400 kJ) for work. 500 kcal (2,100 kJ) are left as balance to serve as reserve for emergency needs.

Based upon the works carried out in different countries the seasonal calorific demand in forest work may be as high as 6,000 - 7,000 kcal (25,100 - 29,300 kJ) per day (ROHMERT and RUTENFRANZ, 1983). However, these are the peak values and yearly average lies lower than these. Under Indian conditions the total energy requirement of a forest worker with 3,240 - 3,840 kcal (13,500 - 16,000 kJ) per 24 hours is assumed to be an upper limit of sustained work (CHRISTENSEN, 1964), with 1,800 - 2,400 kcal (7,500 - 10,000 kJ) as work calories/6 - 8 hours of daily work.

Different work tools have got different energy demands. In felling and cross-cutting by axe, the energy demand of an average Indian worker is 11.8 kcal (49 kJ) per minute (MALETA and SOOD, 1984), while it remained as 9 kcal (38 kJ) per minute when the same work was done with saw. Under similar conditions (HANSSON, LINDHOLM and BIRATH, 1966) the average energy expenditure remained as 4.6 and 5 kcal (19 and 21 kJ) per min in felling with bow saw and two-men cross-cut saw, respectively. While it was about 7.1 kcal (30 kJ)/min in felling with one-man cross-cut saw.

Methods of Measurement of Energy Expenditure

a) Indirect calorimetry

Under field conditions indirect calorimetry is used (LOON and SPOELSTRA, 1971, KAMINSKY, 1980, GRANDJEAN, 1981) in which the uptake of oxygen as LO_2/min by human body during work indicates the energy expenditure. The details of the method are given in chapter No. 3.2.2.4 (Oxygen consumption). The sample of expired air is analysed for its carbon dioxide or oxygen content with the help of chemical or physical gas analysers, such as Orset Chemical Gas Analyser (MALETA and SOOD, 1984) or Paramagnetic Gas Analyser (STAUDT and PIETERS, 1978). Paramagnetic Gas Analysers are fairly accurate under field conditions, but need regular checking and calibration with standard gas mixtures.

The following formulae are used to calculate the oxygen uptake as LO_2/min (cited by MALETA and SOOD, 1984):

$$\text{VO}_2 = \text{V}_\text{I} (\text{F}_{\text{IO}_2} - \text{F}_{\text{EO}_2})$$

where V_I is the volume of inhaled gas in litres/min, which is derived by the relationship

$$\text{V}_\text{I} = \text{V}_\text{E} \frac{100 - (\text{F}_{\text{EO}_2} + \text{F}_{\text{ECO}_2})}{100}$$

where: V_E = volume of exhaled air in litres/min (Pulmonary ventilation)

F_{EO_2} = Oxygen content of exhaled air expressed in percent

F_{ECO_2} = Carbon dioxide content of exhaled air expressed in percent.

F_{IO_2} = Oxygen content of inhaled air expressed in percent.

WEIR (1949) developed a formula (cited by LOON and SPOELSTRA, 1971, STAUDT and PIETERS, 1978) for calculating the energy expenditure from the volume of expired air and its oxygen content:

$$M = 1.05 - 5.015 \times \frac{F_{O_2}}{100} \times V = \text{kcal/min or } 4.18 \text{ kJ/min}$$

F_{O_2} = Oxygen content of expired air expressed as percentage,

V = Volume of expired air in litres/min corrected at STPD.

The calorific value of 1 litre of oxygen varies from 4.68 to 5.01 kcal (19.55 to 21.01 kJ) for respiration quotients of 0.7 and 1.0 (KAMINSKY, 1980), respectively. The average comes out to be about 4.86 kcal (20.31 kJ) per litre of oxygen. The energy expenditure at work can also be calculated by multiplying the uptake of oxygen in litres/min by 4.86 to get the kcal/min.

b) Dietary Recall Method

All the energy needed by human beings is obtained from food. Therefore energy consumption of the workers can also roughly be estimated on the basis of 24-hour dietary recall method of previous days (KAMINSKY, 1980, STAUDT and PIETERS, 1978). Quantities of all different foods coming to the kitchen of workers are recorded and then energetic equivalents are calculated with the help of food composition tables. From these figures the daily energy intake of each worker can be calculated.

c) Energy tables

The energy expenditure during work can also be calculated with the help of energy tables. Elaborate energy tables are available (SPITZER, HETTINGER and KAMINSKY, 1982), which give the energy expenditure as kJ/min for different kinds of activities under different work conditions. The pre-requisite for calculating energy needs with the help of these tables is the time and per-

formance study with exact description of different phases of work. Type of each work element along with its duration in minutes should be recorded, such as distance covered, speed and gradient, lifting height, weight moved, working site and work speed etc. The value of energy need as kJ/min for different work elements should be read from the energy tables and then multiplied by the duration of that work element (STAUDT and PIETERS, 1978). The energy expenditure for different work elements should be summed up to get the total energy expenditure for that activity and when divided by total time will give the average energy needs as kJ/min for that activity.

Table 8 gives an example of energy needs as kJ/min for different activities in tree felling.

The energy expenditure for different workers performing the same task is different and is because of the influences of body parameters, method of work and tools etc. and this interindividual variation may be as high as $\pm 20\%$. For developing an average figure of energy expenditure for a particular type of work a number of workers need to be tested.

The values of energy expenditure given in the tables are standard values for different types of works with different work conditions. For calculating the exact individual requirements, the values need to be corrected for body weight and environmental temperature by using the correction factor given with these tables.

Different authors reported different scales of energy expenditures as limits of continuous performance. According to an international convention (KAMINSKY, 1980) an energy requirement of 4,800 kcal (20,064 kJ) per day has been fixed as a limit for continuous work.

Table 8

Energy Table

Activities and Working Conditions			kJ/min
<u>Tree Felling</u>			
Preparatory Works			
Fixing of Felling Direction			5.4 (4.2-6.3)
Clearing of Stump (without snow)			14.2 (13.4-14.7)
Axe Work			
Cutting of Roots			
(120 years old spruce)	<u>Strokes/min</u>	<u>kJ/Stroke</u>	
in bending	36	1.0	35.8
in standing	32	1.2	39.5
making of fellingcut	32	1.38	43.6 (28.9-54.6)
making of fellingcut (normal speed)			33.5 (26.5-37.8)
Axe Work			
Weight of Axe (kg)	<u>Strokes/min</u>	<u>kJ/Stroke</u>	
0.65	36	1.17	42.2
1.25	34	1.30	44.3
2.00 } Double	33	1.48	48.9
1.25 } Cut	19	1.22	23.3
1.25	35	1.15	40.5
1.25	51	1.87	95.5
0.65	34	1.31	44.7
1.25 } Single	34	1.46	49.8
2.00	35	1.31	46.0

(After Spitzer, Hettinger and Kaminsky, 1982)

LOON (1984) using the criterion of LEHMANN, mentions that a normal worker with normal food intake has an amount of a maximum of 2,200 net kcal available per 8 working hours i.e., approximately 4.6 net kcal/min or in total of 6 kcal/min (25 kJ/min). So in continuous work this figure should not exceed.

CHRISTENSEN (1964) categorizes the work based upon energy expenditure as follows:

Physiological Variables	Physiological Workload					
	Very light	Light	Moderately heavy	Heavy	Very heavy	Extr. heavy
Kilocalories per minute	2.5	2.5-5.0	5.0-7.5	7.5-10	10.0-12.5	>12.5
Kilojoules per minute	10	10-23	23-31	31-42	42-52	>52

3.2.2.5 Body temperature

Heat is a by-product of metabolism in every living cell of the body. About 70 - 80 % of the total energy released in the body, is in the form of heat (LOON, 1984). Heat production in the body proportionately increases with the increasing energy output. In heavy work heat production may be 2 - 4 times higher (APUD, EGLSTRAND and TEGLSTEDT, 1972) than at rest. While in very heavy muscular work, heat production may be as high as 8 - 20 times. Heat stress is reflected by body temperature ranging between 37 - 39° C for light to heavy work.

Therefore, the measurement of body core temperature is also a useful indicator (CHRISTENSEN, 1964) for the permissible upper limits of physical workload and heat stress (for heat stress see chapter 3.3), which is measured by the special thermometers placed in the mouth or in the rectum of the worker. An upper limit of oral and rectal temperature can be fixed as 39°C. But here again the climatic conditions are to play their part. A worker in a cooler temperature with a very high physical workload may feel quite easy, even though his body temperature is high enough, but when working in a hot and humid climate and comparatively at a lower physical workload, may feel to be under a very heavy heat stress. Therefore, the most important temperature may not be oral or rectal, but the temperature of skin. If the average skin temperature rises beyond certain level, which means that the cooling effect of blood circulation through the skin is getting ineffective, then the heat stress may occur within a few minutes. The average skin temperature however, is difficult to assess.

CHRISTENSEN (1964) characterizes the work based upon the body core temperature into the following categories:

Physiological variables	Physiological Workload			
	Moderately heavy	Heavy	Very heavy	Extremely heavy
Rectal temperature	37.5-38.0	38.0-38.5	38.5-39.0	> 39.0

Body temperature is not very sensitive to suddenly changing physical workload.

3.3 HEAT STRESS

3.3.1 Sources of Heat

There are two sources of heat to the human body known as external and internal heat. External heat is the feature of environment and penetrates the body through radiation and convection. While internal heat is the by-product of body metabolism and increases with the increasing physical activity.

In very heavy work the internal heat production may be as high as 20 times (APUD, EGL-STRAND and TELYSTED, 1972) than the quantity of heat released in resting state. The energy expenditure of an average man in the state of rest is about $60 - 70 \text{ W/m}^2$ of the body surface (AXELSON, 1974), while in hard work this energy production may be as high as 200 W/m^2 . Body muscles can utilize less than 25 % of this energy for work, rest 150 W/m^2 is the sole source of internal heat to the body. This extra heat needs to be eliminated for efficient work and the blood circulatory system plays a very important role in carrying the surplus heat from the working muscles to the body surface, from where it is lost by radiation, convection and evaporation. Increased blood flow to the skin for the elimination of excessive heat deprives the muscles of their adequate oxygen supply and therefore, is the reason for impaired working capacity (SUNDBERG, 1974) in hot climates. Heat stress induces sweating and its evaporation on the body surface is the most efficient mechanism of heat elimination. One gram of evaporating water takes away 0.58 kcal (2.4 kJ) of heat from the body surface (GRANDJEAN, 1981). High humidity and low air movements greatly reduce the efficiency of heat exchange mechanism (AXELSON, 1974) by evaporation. Therefore, in hot and humid situations with restricted air movements the heat stress may readily occur.

3.3.2 Effects of heat stress

The most obvious effects of heat stress are increased fatigue, loss in working efficiency, rise in heart rate and blood pressure, increase in body temperature, muscular cramps, unconsciousness and even death (GRANDJEAN, 1981). Heat stress may induce behavioural disturbances such as aggression, hysteria, apathy, loss of normal social inhibitions (WYNDHAM, 1970, cited by AXELSON, 1974) and impairment of mental performance (AXELSON, 1974, GRANDJEAN, 1981) resulting into increased risk of accidents.

The heat stress induces liquid imbalance in the body or dehydration. That is the increased loss of water and salt due to increased sweat rate. A dehydration of 1 - 2 % or even more may readily occur (AXELSON, 1974) with the loss of working capacity and might lead to heat stress disorders. Therefore, water may be drunk regularly and frequently with 1 % salt in it (AXELSON, 1974, STAUDT, 1984) to replenish the deficiency of water and salts due to dehydration and also because of insufficient ability of man to drink voluntarily. To avoid overdoing powder salt can also be used instead of salted water.

3.3.3 Indices of heat stress

For evaluating heat stress environmental temperature, humidity and air movement have to be taken into consideration as dry and wet bulb temperatures, globe temperature and air velocity. The well known indices of heat stress are effective temperature (ET), corrected effective temperature (CET), wet bulb globe temperature (WBGT) and Predicted 4-hours Sweat Rate (P4SR) (AXELSON, 1974, STAUDT, 1984).

Effective temperature (ET) is obtained from empirical nomogram by means of wet and dry bulb temperatures. Wet bulb temperature is measured by a thermometer, whose bulb is covered with a

wetted wick, protected from radiation and exposed to an air current of 2 - 3 m/sec. Natural wet bulb temperature is given by a wet bulb thermometer unprotected from natural air movement and radiation. In corrected effective temperature (CET) dry bulb temperature is substituted by globe temperature. Globe thermometer registers the radiant heat and is an ordinary thermometer fitted to a thin walled blackened copper sphere of 6" diameter:

$$WBGT = 0.7 t_w + 0.3 t_g$$

where WBGT is wet bulb globe temperature, t_w is wet bulb temperature and t_g is globe temperature.

The Predicted 4-Hours Sweat Rate (P4SR) is calculated by measuring the fluid intake during work and taking the weight of worker in the beginning and at the end of work along with urine output (CHRISTENSEN, 1964) and with the help of nomograms and additional formula corrections (AXELSON, 1974). P4SR is the most valid index for estimating the combined effect of external and internal heat, but lacks its general applicability because of laborious calculations.

3.3.4 Limits of heat stress

In 1969 a WHO scientific group proposed tolerance limits of heat stress in terms of CET as follows (cited by AXELSON, 1974):

Sedentary and light work	(2.6 kcal/kg ^h ; 120 W/m ²)	CET 30°C
Moderate work	(4.3 kcal/kg ^h ; 200 W/m ²)	CET 28°C
Heavy work	(6.0 kcal/kg ^h ; 280 W/m ²)	CET 26.5°C

GRANDJEAN (1981) proposed the following temperature limits for acceptable heat stress during day time work:

Overall Consumption of energy kcal/h	Example	Upper limit of temperature (°C)	
		Effective temperature	Temp. with 50 % R.H.
400	Heavy work	26 - 28	30.5 - 33
250	Moderately heavy work	29 - 31	34 - 37
100	light sendentary work	33 - 35	40 - 44

A sweat rate of 1 litre/hour indicates an upper permissable limit of heat stress in 4 hours of work shift (CHRISTENSEN, 1964).

3.4 WORK CAPACITY

3.4.1 Definition and Importance

Work capacity or performance capacity of a worker can be defined as the capability of his cardio-vascular system to supply the adequate quantity of oxygen to the working muscles and is denoted by such physiological parameters as "aerobic work capacity" or maximal oxygen uptake capacity (VO_2 -max.) (CHRISTENSEN, 1964, DAVIES, 1979). The maximal oxygen uptake is the quantity of oxygen in litres/min which a worker can absorb at a maximum rhythmic workload. The higher the value of maximal oxygen uptake the more capable a worker is. A fit worker can be defined as the worker whoes performance capacity is comparable with the sustained energy demands of the work.

Carefull evaluation of workers on the basis of their work capacity is needed to eliminate the weaker ones and to select the right man for the right job. It is specially important when the workers work in a party, because the weak worker works at a higher physical cost, get fatigued early and blames the job rather than his own inadequacy (BROUHA, cited by CHRISTENSEN, 1964) and influences the attitude of other co-workers. Rating of workers on the basis of physical work capacity is also important for creating a uniformity in the group (CHRISTENSEN, 1964) for better labour management reasons.

3.4.2 Physiological Basis of Work Capacity

For work human body needs energy. The immediate sources of energy to the working muscle is the breaking down of high energy phosphates (ATP) to the low energy phosphate (ADP) with the liberation of energy equivalent to 8,000 calories per mol. This is a reversible process and the rebuilding of higher energy phosphates from the low energy phosphates requires again energy. This energy is obtained through the oxidation of food and anaerobic glycolysis (ANDERSON, 1971) with carbon dioxide and water as by-products. Anaerobic glycolysis is an emergency reaction which provides additional energy when normal aerobic process of energy liberation is lacking behind in meeting the body energy demands. As oxygen is the main factor in this process therefore, its quantity absorbed in l/min gives direct indications of the efficiency of pulmonary and cardio-vascular systems for absorption and utilization of oxygen in liberating the desired quantity of energy through increased oxidation of food material and consequently the physical working capacity.

3.4.3 Maximal Oxygen Uptake

The maximal oxygen uptake of the workers is determined under laboratory conditions in the presence of medical doctor. The standard equipment for this test is a bicycle ergometer with mechanical or electrical braking system, a device for counting the revolution of wheel, arrangement for measuring the load given in kpm or Watts and for recording the heart rate of the subject during test. The procedure of expired gas metering, gas analysis and calculation of oxygen uptake is given under chapter 3.2.2.3.

The oxygen requirement of the subject at each workload is determined whereby a further increase in the work does not cause a corresponding increase in oxygen uptake (ANDERSON, 1971). The heart rate of the worker is monitored at each workload either manually or by means of photo-electric cell attached to the ear lobe of the worker.

There exists a linear relationship between heart rate, oxygen uptake and workload expressed in kpm/min (CHRISTENSEN, 1964). Therefore, instead of loading the worker upto a maximum limit, which some times proves dangerous, the maximal oxygen uptake can also be determined by extrapolating the graph between heart rate and oxygen uptake at the two submaximal loads to the predicted maximum heart rate. The maximum heart rate is influenced by age and decreases by about 10 beats/min per decade (MELLEROWICZ and SMODLAKA, 1981). The healthy worker at the age between 20 - 25 years have got a maximum heart rate of 195 beats/min (ROHMERT and RUTENFRANZ, 1983) which comes down to about 150 at the age of 50 years (MELLEROWICZ and SMODLAKA, 1981). For practical purposes the predicted maximum heart rate is taken as 170 beats/min.

The determination of maximal oxygen uptake requires a well equipped laboratory and the procedure is also laborious and time consuming. The alternate and fairly accurate method is to subject the prospective worker to measurable load (CHRISTENSEN, 1964) and to record his physiological response. There are different methods for loading the workers. Simple step test, tread mill or bicycle ergometer can be used for this purpose.

The most useful physiological response at a given test load is the heart rate. There exists a linear relationship between work-load expressed in kpm/min and heart rate (CHRISTENSEN, 1964). The fit workers will have a less steep increase in heart rate with increasing load than the unfit worker and this is the basis of so called "Performance Pulse Index" (PPI) (MÜLLER cited by CHRISTENSEN, 1964). Moreover, when this trend is extrapolated to a predicted maximum heart rate of 170 one gets the "Physical working capacity" (PWC₁₇₀) (WAHLUND, 1948, cited by ROHMERT and RUTENFRANZ, 1983) and later on modified by HOLGREN (1961) as W_{170} defined as "Rate of Work at a heart rate of 170 per minute". PWC₁₇₀ or W_{170} is equally a valid estimate as maximal oxygen uptake to test the fitness of workers.

The maximal oxygen uptake can also be calculated with fair accuracy by entering the figures of work and heart rate in a nomogram (Fig. 13, F. ASTRAND cited by ROHMERT and RUTENFRANZ, 1983). So calculated values of maximal oxygen uptake should be corrected for age by multiplying with correction factors (table 9).

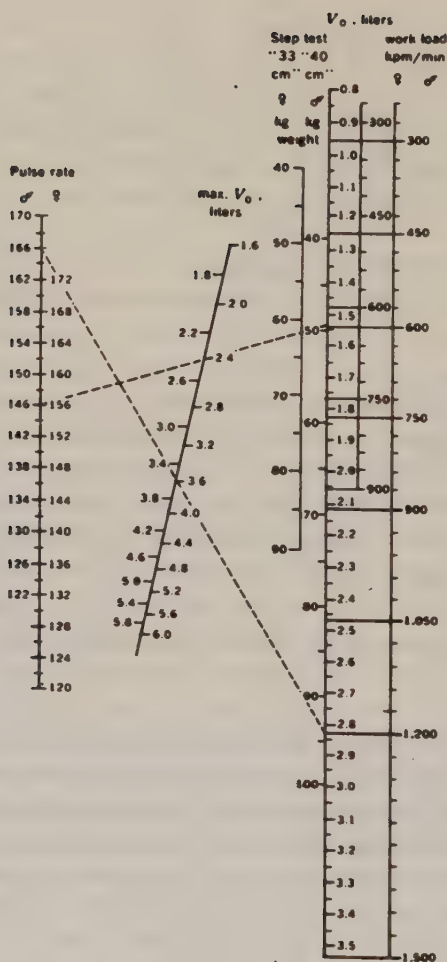


Fig.13: Nomogram for calculating the maximal oxygen uptake from heart rate and work performed (I. Astrand, 1960)

Table 9: Correction factors for age

Age	Factor
15 - 24	1.10
25 - 34	1.00
35 - 39	0.87
40 - 44	0.83
45 - 49	0.78
50 - 54	0.75
55 - 59	0.71
60 - 64	0.68
= 65	0.65

The maximal oxygen uptake (work capacity) is affected by age, sex (Fig. 14) and training. ASTRAND (1958, cited by CHRISTENSEN, 1964) measured a maximal oxygen uptake of 3.01 l/min for the male subjects of 25 years of age, it decreased to 2.23 l/min for the persons of 50 years of age. For females it decreased from 2.23 - 1.85 l/min over almost the same variations of age as for men. Women have about 25 % and 17 % less maximal oxygen uptake in the age of 25 and about 50 years respectively than men. Level of training also effects the maximal oxygen uptake. The maximal oxygen uptake remained double in case of highly trained persons than untrained (MELLEROWICZ and NOWACKI, cited by MELLEROWICZ and SMODLAKA, 1981), while on equal loads the difference remained statistically insignificant (MELLEROWICZ and SMODLAKA, 1981).

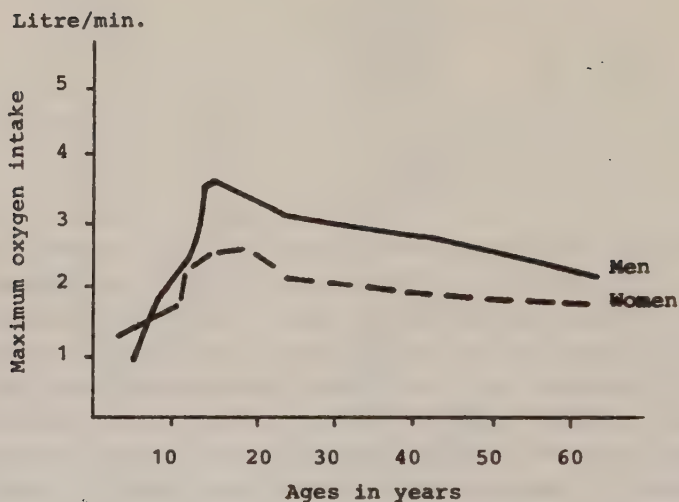


Fig.14: Maximum performance, measured by maximum oxygen intake (ordinate) during a standard task for men and women of various ages. (I. Astrand, 1960, P.O. Astrand, 1952)

3.4.4 PERFORMANCE PULSE INDEX (PPI)

A very informative sub-maximal test which determines the sustained performance capacity of a worker is the Performance Pulse Index (PPI) given by E. A. MÜLLER (cited by KAMINSKY, 1980). It is a simple procedure by which the performance capacity of a worker is tested on the basis of heart rate during a regular and exactly defined work on a bicycle ergometer (KAMINSKY, 1980, SCHNAUBER, 1979).

PPI is the mean increase in heart rate each minute by an exact and continuously increasing load of 1 kpm/sec or 60 kpm/min after every minute. A total time of 15 minutes is needed for this test.

A bicycle ergometer is used for this purpose with magnetic breaking system. The test begins with a resting period of 3 minutes, 2 minutes for free run without load. In continuity follows the 10 minutes long test with continuously increasing load from 0 - 10 kpm/sec. Load will automatically be controlled by the rate of pedalling of bicycle ergometer as shown by a revolution counter mounted on the ergometer upto a maximum pedalling rate of 60 revolutions/min. The bicycle ergometer allows other test arrangements with different drives and constant performance. The PPI is calculated as regression between pulse frequency read after every minute and work output in Watts (Fig. 15).

Numerous experiments carried out report that PPI is not only an expression of more or less strong muscular development, but it can also give informations on the performance range of lungs, heart and overall blood circulatory system. For well trained and strong persons, the mean increase in pulse as shown by PPI lies between 2.0 to 3.5 and for weak persons and ladies between 7 to 8, where as deviations upto 15 % are also possible.

Test: <i>B</i>	PERFORMANCE PULSE INDEX	Date. <i>8.3.70</i>
No. <i>10</i>		Time. <i>8⁰⁰</i>

Test Person

VP ♂

Remarks: *without previous physical work.*

Time min.	Performance Watts	Pulse/min.	Remarks
0 - 1	} Rest	85	<i>85 Rp</i>
1 - 2		84	
2 - 3		87	
3 - 4	0	92	
4 - 5	0	89	
5 - 6	10	86	
6 - 7	20	89	
7 - 8	30	93	
8 - 9	40	93	
9 - 10	50	98	
10 - 11	60	98	
11 - 12	70	104	
12 - 13	80	107	
13 - 14	90	110	
14 - 15	100	114	

Calculations: X= Pulse in the middle of each minute

Y= Performance at the end of each minute

X_a	X_b	Y_a	Y_b	$X_b - X_a$	$Y_b - Y_a$	$(X_b - X_a) \cdot (Y_b - Y_a)$	$(Y_b - Y_a)^2$
86	114	1	10	28	9	252	81
89	110	2	9	21	7	147	49
93	107	3	8	14	5	70	25
93	104	4	7	11	3	33	9
98	98	5	6	0	1	0	1
Tot.						502	165

$$\sum (X_b - X_a) \cdot (Y_b - Y_a) : \sum (Y_b - Y_a)^2 = PPI$$

$$\dots \frac{502}{165} \dots = 3.042$$

Fig.15: Test proforma for the calculation of Performance Pulse Index (After E.A. Müller).

The PPI is also the increase of pulse frequency with the increase of cycling work of about 60 kpm/min (approximately 10 Watts/min) = 2.51.kJ/min (0.6 kcal) = 0.12 l/min of oxygen as denoted by the following equation:

$$\frac{\text{Oxygen uptake}}{\text{Working pulse}} = \frac{0.12}{\text{PPI}}$$

The maximum oxygen uptake for the persons upto 34 years age, with the pulse rising about 100 beats/min over the resting pulse corresponds to the following expressions:

$$\text{Maximum oxygen up-take} = \frac{12}{\text{PPI}}$$

In this the oxygen consumption in resting state as 0.2 l/min is not included. The maximum oxygen up-take is calculated from PPI after E. A. MÜLLER (cited by KAMINSKY, 1980):

$$\text{Maximum oxygen up-take} = \frac{12}{\text{PPI}} + 0.2 \text{ l/min.}$$

The PPI besides its use as an indicator of fitness for manual work can also be used to calculate the work calories at the predicted pulse or actual pulse, as is explained by the following example.

In cycling the energy expenditure for different persons for each kpm/min work with minor deviations is 0.04 kJ/min (0.01 kcal). The PPI is reflected as the increase in pulse frequency with a 60 kpm/min increase in work. This increase corresponds to an energy expenditure of 2.5 kJ (0.6 kcal). The relation PPI: 2.5 is however the lowest pulse rise/kJ, which a person can present under favourable conditions of blood circulation. It is only possible to show the effect of dynamic work under relatively favourable and less fatigueing conditions like that of cycling:

$$\text{Predicted pulse} = \frac{\text{Energy expenditure}}{2.5} \times \text{PPI}$$

Say for example that the energy expenditure measured is 18.8 kJ (4.5 kcal)/min and the test person has a PPI of 2.68, so by the use of formula the result is as follows:

$$\text{Predicted pulse} = \frac{18.8 \times 2.68}{2.5} = 20.3$$

This means an increase of 20.3 beats/min above the resting pulse. In the tests lasting 10 minutes, the formula can be modified. If the total pulse during work is 200 beats/min the energy expenditure is calculated as under:

$$\text{Energy expenditure} = \frac{200 \times 2.5}{2.68} = 187 \text{ kJ (45 kcal) in } 10 \text{ minutes or } 18.7 \text{ kJ/min.}$$

4 MATERIAL AND METHODS

4.1 MATERIAL

With a group of six volunteer workers, time, productivity and heart rate studies were carried out in tree felling and conversion work in the irrigated plantation of Changa Manga. The workers first worked with conventional tools (Level-I) followed by improved tools with training (Level-II) and in different work party sizes. The purpose of the study was to see the efficiency of improved tools in increasing the work productivity and reducing the physical workload.

The Changa Manga Plantation was chosen for the purpose of this study because of being an ideal representative of well managed state forests in the plains of Pakistan.

4.1.1 Changa Manga Forest Plantation

The Changa Manga plantation is situated about 65 km south of the city of Lahore in the province of Punjab (Fig. 16). It was raised in the year 1866 and is the first plantation of its kind in the Indian subcontinent. The object of its establishment was to supply firewood to the newly colonized areas with the extension of irrigation system. The plantation covers an area of 5,000 ha divided into 5 blocks and 232 compartments of varying sizes and belongs to the Punjab Forest Department, as a part of Kasur Forest Division under the charge of a Sub-divisional Forest Officer.

The **tree species** on which the plantation was first based was pure shisham (Dalbergia sissoo) along with some semul (Bombax cieba) planted on the banks of water channels. Mulberry (Morus alba) came self sown with the irrigation water and developed well under the canopy of shisham. Since then the mulberry stood

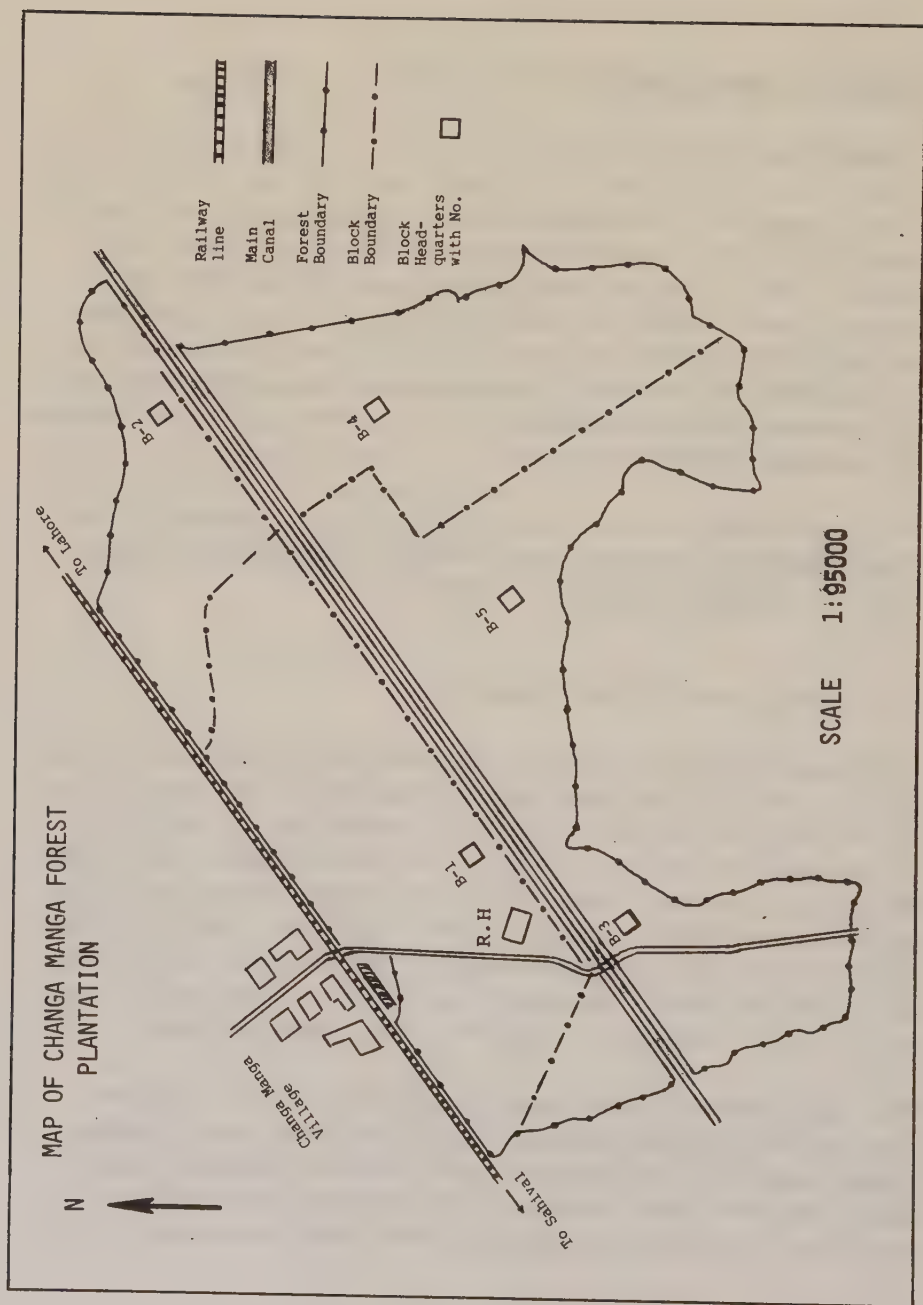


Fig. 16

second to shisham as a tree species and raising of crops as an admixture of shisham and mulberry became a regular practice. The rotation age for these species is 22 years, after which the whole of mulberry and most of shisham is removed except 35 - 45 selected trees of shisham/hectare as standards to grow upto 2nd or 3rd rotation for the production of timber. At the end of 3rd rotation a stand looks like a 3-storied forest, with an under storey of 22 years mulberry and shisham, a second storey of 44 and an over storey of 66 years shisham trees.

Harvesting of trees starts in the month of August/September and remains continuous up to the month of January/February. Every year about 150 - 200 hectares are cleared by employing labour working with hand tools.

Changa Manga is the most productive plantation in Punjab with the following **production** and **revenue** figures for the years 1983 - 84 (source: office record of the plantation):

Commodity	Production m ³	Revenue thousand Rupees
Timber		
shisham	3,117	
mulberry	2,044	
others	2,005	
	7,166	16,494
Firewood (stacked)		
mixed	26,062	2,616
Other Products	-	1,094
Total	33,228	20,204

Shisham is a popular furniture wood in the country while mulberry from the plantations finds its use in sports goods industry. Sericulture is also flourishing on the leaves of mulberry from the plantation.

The area cleared is regenerated in the subsequent springs in the month of March by planting root-shoot cuttings of mulberry and shisham at a spacing of about 2 x 3 meters. The root-shoot cuttings are made from the plants raised in temporary nurseries. Shisham also regenerates by itself from stump-sprouts and root-suckers.

The **workers** who carry out different forestry operations are known as Beldars and are almost permanent, living in small labour colonies in each block of the plantation. The table below gives the number of registered workers living in the plantation:

Block No.	No. of workers
I	101
II	72
III	53
IV	80
V	44
central colony	59
Total	409

These workers also have concessions from the forest department like free accomodation, a piece of land, certain number of cattles, free grazing, grass cutting and firewood for domestic use.

Payments and Rates: In timber harvesting the workers are paid on piecerate, but mostly indirectly through the forest contractors, who further sub-lets the work among the workers. The piece-rates are decided by the forest department in reference to a very rudimentary time and productivity studies, but one gets no satisfactory answer that who, where and when made this study. The prevailing piece-rates for timber harvesting at Changa Manga are given as under:

- Forest department Vs.		Forest Contractor
shisham timber		Rs. 88.25/m ³
mulberry timber		Rs. 70.60/m ³
Firewood (stacked)		Rs. 11.30/m ³
- Contractor Vs.		Labour
shisham timber		Rs. 14/piece
billets of shisham and mulberry		Rs. 2/piece
Firewood stacked		Rs. 7.95/m ³

These rates also include the extraction of all timber and firewood up to the compartment road side.

In other forestry works (desiltation and opening of irrigation channels, nursery works, pulling out of plants from the nursery, planting, weeding, cleaning and thinning etc.) the workers are paid on a daily wage rate of Rs. 20 by the forest department.

4.1.2 Experimental Site and Choice of Workers

Two rectangular plots as representative of crop and species were selected in compartment No. 157 and 12 with a total area of 2.5 hectares. The crop consisted of a mixture of shisham and mulberry.

Each tree in these plots was numbered, measured for its average DBH and height with the help of tree cliper and "SUUNTO" Clinometer. The angle of lean of trees if any was also measured by using a plumb bob with 2 meters long string (denoted by P), placed at such a point on the leaning side of the stem until it touched the ground. The horizontal distance between plumb bob and base of the tree (denoted by b) was noted. P kept as numerator and b as denominator gave the value of tangent for the angle of lean. Tangent values were converted to their corresponding angles. Number of branches of first order and thicker than 5 cm were also counted for each tree.

Most of the Level-I observations were made in the compartment No. 157. But due to the end of harvesting operation, the experiment site had to be changed. In view of the needs of the study, the plantation authorities, as a very special case, provided a new area in compartment No. 12 from the next years felling programme. So remaining Level-I and all of Level-II observations were recorded in this area.

The ground was almost level and the soil was deep alluvium. The undergrowth of low scrubs like Lantana indica, Xanthium strumarium and grasses was quite common at the start of experiment, but withered out and disappeared almost completely at the end of experiment in the month of February.

The climate of the area is very severe. Summers are extremely hot and dry, with day temperatures as high as 46°C in the month of June, while in the month of January, night temperature often drops down to freezing. The area is arid with an average annual rainfall of about 483 mm (CHAMPION et al., 1965), highly erratic and mostly received in the months of July and August as occasional monsoon showers.

Six volunteer workers (BELDARS) were chosen, who always worked together in a party in tree felling and conversion. These workers were of an average age of 25 years, 54 kg body weight, 170 cm in height and had 9 years of experience in timber harvesting. Individual details are given in table 10.

Table 10: Particulars of the workers used in the experiment

Worker No.	Name	Age (years)	Weight (kg)	Height (cm)	Experience (years)
1.	M. Anwar s/o. Pehlwan	22	59	172	6
2.	M. Anwar s/o. Barkat	25	52	166	10
3.	M. Abbas s/o. Nawab Din	22	55	170	10
4.	Habibullah s/o. Ghulam Mohammad	22	57	174	10
5.	M. Ishag s/o. Nawab Din	19	48	163	4
6.	Shamahoon s/o. Dost Mohammad	39	50	173	16
Average		25	54	170	9

4.2 STUDY LEVELS

4.2.1 Study Plan

Time, productivity and heart rate studies in tree felling and conversion were carried out in two different levels. In Level-I, the workers worked in their traditional way and with conventional tools and in Level- II, the workers were provided with improved hand tools and a two weeks training in the proper work methods and use of these tools (Fig. 17).

Observations on time, productivity and heart rate were made by using the workers in the **party sizes** of 2, 3 and 4 persons in each study level. Mostly only the four workers were used in the party sizes of 2 and 4, but some time all the six were employed when the observations were to be made in the party size of 3. In the work party sizes of 2 and 3, mostly the two parties of the same size worked parallel to each other. Attempt was also made to keep the same workers in the same party size throughout.

4.2.2 Tools

In study Level-I the workers worked with their traditional tools. The details of these tools is given in the table 11.

Fig.17: Schematic Presentation of Study Plan

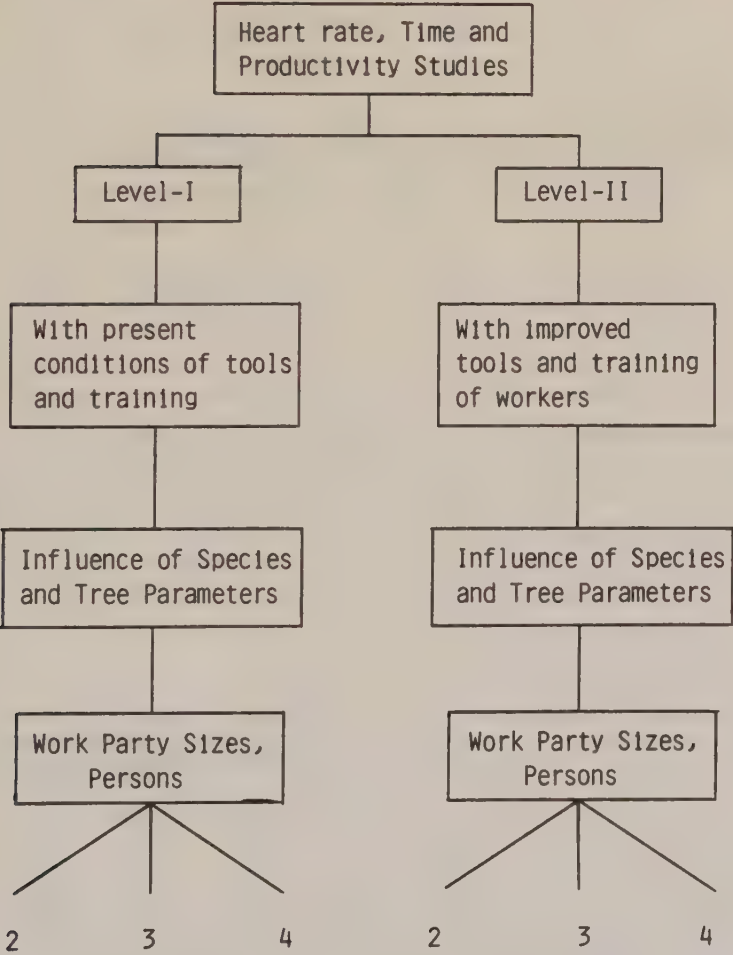


Table 11: Tools in Level-I studies

Type of tools	Particulars	No
Axes	local (for details see table 12)	4
Felling wedges	-	-
Wedges		
Cross-cutting	about 16 cm long and 2.5 cm in dia. made out of an iron bar with one end flattened	2
Cross-cut saws	140 cm long peg-tooth	2

The axes were with a round eye and handle (Fig. 18), locally made from discarded rails with an average weight of 1.96 kg, 86 cm total length and 76 cm handle length. The handles were made of mulberry wood with an average dia. of 3.3 cm. The details of each axe is given in the following table 12.

Table 12: Axes used by the workers

Axe with reference to owner	Weight kg	Total Length cm	Handle Length cm
Axe (worker No. 1)	1.90	85	76.5
Axe (worker No. 2)	2.50	85	73.5
Axe (worker No. 3)	1.78	88	78.0
Axe (worker No. 4)	1.65	85	75.5
Average	1.96	86	76

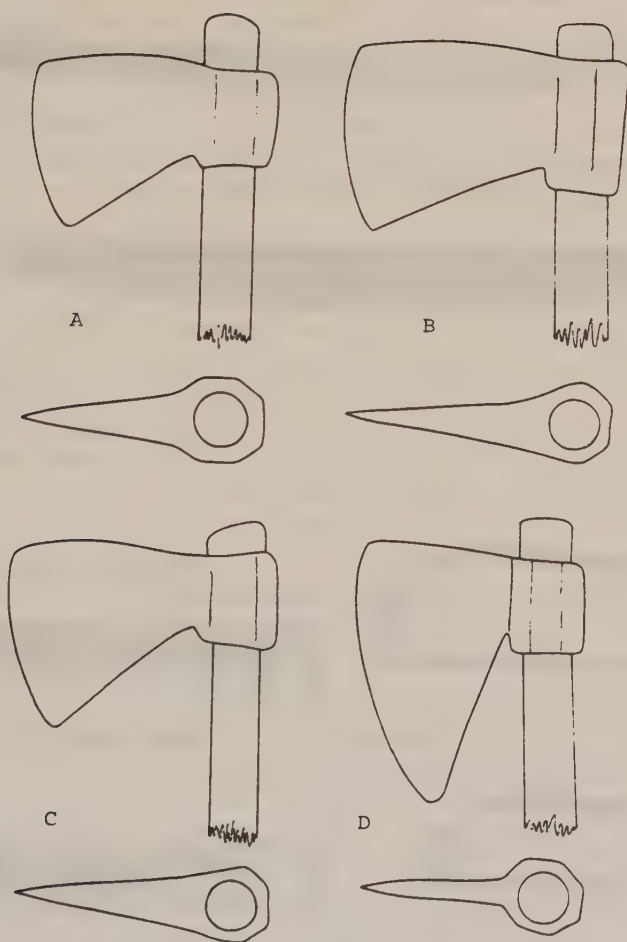


Fig.18:Some common forms of axes used in Changa
Manga for tree felling and conversion,
2/9 of the actual size.

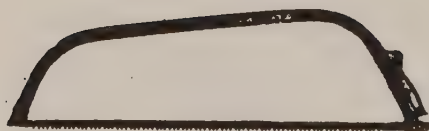
Raker-tooth Crosscut Saw



Peg-tooth Crosscut Saw



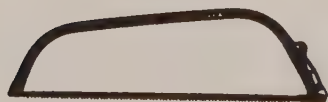
Bowsaws



Bowsaws Blades



Raker-tooth (2:1)



Peg-tooth

Fig:19: Crosscut saws and bowsaws used in the experiment

These axes were used for felling, cross-cutting, debranching and firewood conversion. The peg-tooth crosscut saws were used only for cross-cutting of thick pieces.

In **study Level-II**, the workers used two crosscut saws (raker tooth), four bowsaws, four bill-hooks and steel wedges for felling and cross-cutting. Details of these tools are given in table 13 (Fig. 19).

Table 13: Tools in Level-II studies

Type of tool	Particulars	No
cross-cut saws	Raker-tooth 4:1 (Sandvikens Ternverks A.B), Length 140 cm	2
Bowsaws	Sandvik, peg-tooth hard tempered, 76 cm long	2
Bowsaws	Sandvik, raker-tooth (2:1) hard tempered, 91,5 cm long	2
Wedges Felling	Steel	2
Wedges cross-cut	Steel	2
Wedges cross-cut (bowsaw)	Steel	4

The German axe because of design features did not prove better in comparison to local axe for making of undercut in felling of shisham. The local axe gave a better penetration because of more acute sharpening angle. Therefore, the workers used their own axe in such situations.

4.2.3 Work Methods

Level-I

- Felling: Purely with axe. Two workers work at the same cut from opposite sides. The cuts make an angle of $45 - 60^{\circ}$ with each other. There is no concept of under-cut and back-cut, therefore, the tree fell in a pre-determined direction because of lean or one sided development of crown. Due to the absence of under-cut the heavy and leaning trees of shisham mostly split at the butt end. Saw is very rarely used in felling except in thick shisham trees as final remedy, when the axe work is difficult and ineffective further.
- Hang-ups: Due to lack of directional felling there are frequent hang-ups. The hang-ups are either released by moving the butt end backwards with the help of levers, by cutting about 2 m long butt log or by climbing the standing tree and chopping off the stuck-up branches. The last techniques is very risky and chances of accident are high.
- Debranching: Debranching is done with axe and is very heavy work, because the branches especially of shisham are very thick and the workers often has to work in cramped positions.
- Firewood Conversion: The defective portions and the branches thinner than 15 cm dia. (o.b.) and thicker than 3 cm dia. (o.b.) are to be converted into firewood pieces of about 1.5 m length. This operation is performed with the axe only. The work is especially risky when the workers clear off thinner pieces held in one hand and using the axe with the other. Injuries to the knee and left hand are quite common.

- **Measuring:** For measuring no standard instrument like measuring tape or caliper is used. Timber length are decided with axe handle. Cross-cutting positions are marked either with axe, wet soil or saliva of the mouth.
- **Cross-cutting:** Cross-cutting is carried out with 2-men crosscut saw (peg-tooth) in almost all possible work positions. Saw binds are avoided by the use of iron wedges, or when the pieces to be cut is not too heavy, by supporting it on the levers. Thicker Shisham is always hazardous in cross-cutting.
- **Maintenance of Tools:** When the handles of axes broke they are made from the dried and split mulberry wood either by the workers themselves or from the village carpenter on payment. The axes were sharpened daily with a stone by the workers mostly at their homes. In case the edge of the axe is damaged (bent or broken), it is got reshaped and tempered by village blacksmith. As the axes belong to the workers therefore, their repair and maintenance was the personal liability of workers. Crosscut saws are the property of forest department and are issued to the workers at the start of felling season and are recollected at the end of work. Crosscut saws were given one sharpening daily either at the start of work or somewhere in between or sometimes even two, while cutting shisham, because of extra hard wood with mineral deposit. Sharpening of crosscut saws was carried out by a professional man called mistri and is employed by the forest department on monthly salary. Mistri daily visited each work party and sharpened the saw right at the work place by fixing it in a cut given in the stump or a log or supported on the axe or the workers presented the saws to mistri at his house each day at the end of work. For setting no gauge and tool is used. The teeth of the saw are alternately bent by the strokes with the back of the axe and checked visually.

Level-II

- Felling: Comprised of clearing the site, removal of dead bark from the butt with an axe. Determination of direction of fall, giving the under-cut with cross-cut saw (raker-tooth, 4:1) in case the trees were thicker than 30 cm otherwise with bowsaw (raker-tooth 2:1), worked by two persons. The under-cut was made as near to the ground as possible and worked up to about $\frac{1}{3}$ of the butt dia. in kneeling body posture. The under-cut was opened with axe at an angle of about 45° . Back-cut likewise was given with cross-cut saw or bowsaw 3 - 5 cm higher than the under-cut, leaving a proper amount of holding wood. Need for felling wedges rarely arose because of a natural lean in the trees or one sided development of crowns. Proper placing of under and back-cuts worked fairly well, when directional felling was needed.
- Hang-ups: No serious hang-up occurred during Level-II studies, because of a perfect control over the direction of fall. Moreover, no special device was at hand like that of power puller for releasing the hang-up trees except a turning hook.
- Debranching: Debranching was mostly done with bowsaw or even crosscut saw when the branches were too thick (in case of heavy shisham trees). In certain cases the use of axe remained indispensable for debranching.
- Firewood Conversion: For firewood conversion bill-hooks and bowsaws were used in combination. Bill-hooks were used for the removal of brush-wood and conversion of firewood up to 3-4 cm thickness. The bowsaws in firewood conversion were either worked by one man or even two men, when the piece were thick. A pocket made out of strong cloth was attached to the waist of each worker with the help of a belt for keeping the wedges to be used with bowsaws.

- Measuring: For measuring the workers were provided with 6 feet long measuring rod, bearing the marks for 4, 5 and 5 1/2 feet, with which they measured different timber length and prospective cross-cut points were marked with the help of white chalks kept in the pocket of each worker.
- Cross-Cutting: For cross-cutting both raker-tooth crosscut saw (4:1) and raker-tooth bowsaw (2:1) were used, depending upon the thickness of the timber. Use of wedges was frequent, therefore, very less saw binds occurred. Cross-cutting of heavy shisham trees always proved hazardous.
- Maintenance of Tools: In Level-II studies, though the workers attended the training in tool maintenance, but they could not master the art especially in correct filing of the saw teeth and the training could not be prolonged because of time constraint. Therefore, the maintenance of raker-tooth saw was mostly done by the technicians of PFI, at headquarters. Before the start of Level-II observations, mistri (professional man for saw maintenance) sharpened both the raker-tooth saws used in the experiment. Mistri also joined the workers in the saw maintenance part of the training and mastered the art very quickly. The axes and bill-hooks were sharpened by the workers themselves as usual. The worn out blades of bowsaws were replaced with the new ones.

The raker-tooth cross-cut saws did not require so frequent sharpening as peg-tooth cross-cut saws and were given a major sharpening once in a week or checking of the setting or small touches to the cutting teeth right in the field when ever needed. For the maintenance of raker-tooth cross-cut saws the instructions and specifications given in the ILO Training Manual (1970) for the maintenance of logging hand tools were followed. The raker-tooth cross-cut saws were sharpened and set with the following features:

- cutting teeth angle = 70°
- raker depth = 0.3 mm
- raker angle = 90°

A cutting teeth setting of 0.3 mm was chosen after trying many settings on shisham and mulberry. Raker depths less than 0.3 mm could not be tried because it was the minimum possible with the raker adjusters at hand.

4.2.4 Training of workers

Study Level-I was to be followed by study level-II, in which the workers were to work with improved tools and proper work methods. Before expecting any change in work productivity and workload with the use of new tools and techniques, it was essential that the workers should be given training in proper work methods and use and maintenance of these tools.

A period of 2 weeks training was estimated in view of time pressure and also because the workers were professional wood cutters and had enough experience already. The training of workers started from 22.12.1984 and lasted up to 6.1.1985, comprising of almost 14 work days. In the first half of this period, training was conducted by the technicians of the Pakistan Forest Institute (PFI) and in the second half a German Expert (Mr. J. Wolf) imparted the training to the workers with more emphasis on tool maintenance and practical aspects of tree felling and conversion work.

The training of workers was conducted right in the forest with the following outlines:

- Introduction concerning new tools and their design features:
The workers were given an introduction about the new tools such as raker-tooth crosscut saws and bowsaws. Shape and types of different saw teeth their design features and functions.

Advantages of raker-tooth crosscut saws and bowsaw over peg-tooth saws. Basic design features of axes and handles. Advantages of eleptical eye and curved handle over round eye and round handle. Basic tree forms, straight and leaning trees.

- Felling: Different felling cuts and their importance, location of felling cuts and felling direction, importance of holding wood, making of under-cut with saw and axes, making of backcut with saw, use of wedges in felling, felling of leaning trees, suitable body postures during work, directional felling and its importance. Felling of trees in a desired direction by proper placing of felling cuts, with the use of wedges and power puller. Visit to many standing trees and on the spot-discussion about their felling, determination of felling direction and location of felling cuts.
- Hang-ups: Precautions to avoid hang-ups, releasing of hang-ups with the use of power pullers.
- Debranching: Debranching with bowsaw and axe, precautions to avoid saw binds in debranching.
- Cross-cutting: Judgement of compression and tension in the lying stems. Suitable body postures and way of making cutting strokes, possibilities of saw binds and their types, use of wedges in cross-cutting.
- Firewood conversion: Cutting of firewood with bill-hook, advantages of bill-hook over axe in firewood cutting, use of bowsaw in the conversion of firewood.
- For the purpose of practice the workers felled and converted about 60 mulberry and shisham trees with improved tools and methods with full attention given to the methodology of work. Made hundreds of trial cuts with raker-tooth cross-cut saw and bowsaw, with special attention to body posture in felling and

cross-cutting. In this exercise they independently planned the felling cuts and fixing of felling direction.

- Maintenance of improved tools: sharpening of axe and bill-hook with hand stone, basic filing practice, filing of cutting teeth, checking of tooth angle, saw setting and its importance, method of saw setting and use of setting indicator, optimum saw setting. Sharpening and setting of raker-tooth and use of raker adjuster.

4.2.5 Payments and Incentives

During the whole period of study mostly four workers carried out tree harvesting work. The others two did the measuring of work results and very rarely employed in tree felling and conversion. In Level-I studies those carrying out tree harvesting worked for the forest contractor on piece-rate and earned about Rs. 22.42/man day. In addition to this they were also paid a sum of Rs. 7/person for disturbance during taking of their pulse. This all together made up about Rs. 30/man day. The others two doing the measuring of work results were paid at Rs. 30/man day.

Due to the end of normal harvesting operations in compartment No. 157, the site of experiment was changed to compartment No. 12 and the work was continued only in the interest of experiment. In this new area the Level-II observations were made and the workers were offered a daily wage rate of Rs. 30 which they willingly accepted.

Although the earnings of workers almost remained the same throughout, but there is a big change of incentive from piece-rate to time-rate in Level-I and Level-II studies.

4.3 RECORDING OF TIME AND WORK RESULTS

4.3.1 Identification of Work Elements

Before starting the actual time studies a method study was made, which is supposed to be the first step in work study investigations (WITTERING, 1973). Importance of method study lies in finding better way of doing things and it contributes to improved efficiency by getting rid of unnecessary work, avoidable delays and other forms of waste. Different work elements in a work cycle of tree felling and conversion were identified according to HÖFLE (1969), but in a much modified form to suit our purpose.

In this context a **work cycle** is defined as the time period between finishing of first tree and finishing of the following tree without break. The following work elements have been distinguished:

- Preparation

Preparation included the time of all activities, which a worker did to start and close the work. Preparation started with the coming of the worker to a place in the forest where he leaved his mean of transport, unloaded the tools, fixed the saw handles, carried the tools and walked through the stand until he reached the first tree to be felled. At the close of days work, preparation began when the last tree was finished and included the time of collection of tools, carrying the tools and walk through the stand until the worker reached to the starting point, dismantled the saw handles and preparation ended with the loading back of tools.

- Walk or Searching for Tree

Started with the picking up of tools from the site of finished tree and walking to the next tree. Walk ended when the worker put down his tools or straight away got attentive to the tree for felling.

- **Felling**

Started with picking up of the felling tools, clearing of the felling site, cutting of climbers, removing the bark at the place of prospective felling cuts, determination of felling direction, making of different felling cuts, wedging, until the tree came down to the ground and the butt end was freed from the stump and cleaned or the tree got hung-up.

- **Hang-up**

Hang-up time started when the worker got attentive to the hung-up tree and includes all the activities to bring the hung-up tree down, such as cutting of attached holding wood, shaking of tree, pulling back the butt end with levers, cutting of 2 m long butt piece, cutting of stuck-up branches by climbing up the standing tree etc. until the tree came down to the ground and the worker was attentive to some other job.

- **Debranching**

Started with the picking up of tools with the idea of debranching, cutting of branches from the main stem, driving in of the wedges, releasing saw binds until the last branch was removed and the worker put down the tools or was attentive to the other jobs.

- **Firewood Conversion**

Started with the picking up of firewood conversion tools, cutting of firewood with axe, saw or bill-hook and ended with the putting down of these tools or the worker was attentive to the other jobs.

- **Measuring**

Started with the picking up of the measuring instruments, measuring and marking of lengths until the worker put back the measuring instruments or was attentive to the other jobs.

- **Cross-cutting**

Started with the picking up of the cross-cutting tools, clearing the work place, turning of timber pieces for the purpose of cross-cutting, cross-cutting, driving in of wedges and releasing of saw binds until the worker put back the tools or was attentive to other jobs.

- **Operational Delay**

Time taken in the sharpening of tools by the worker, fixing of loose handles, replacing of broken handles and changing of worn out bowsaw blade.

- **Personal Delay**

Time of short rests, smoking, drinking, chatting, waiting for the other colleagues, going to bring water or to ease oneself.

- **Not Accountable Time**

Time lost in conversation with the time keeper, forest officer, disruptions due to measuring work and taking of ergonomic observations.

4.3.2 Time Studies

There are different methods of time studies such as,

- Zero-stop Method
- Continuous-timing Method
- Multimoment.

But multimoment is the most commonly used time study method in forestry these days.

With this method, it is not the time duration of an activity or work element which is taken, but the frequency of its occurrence is recorded (ANONYMOUS, 1976).

In this method a continuously running mechanical stop watch and a recording proforma with columns for each activity or work element are needed. After a specified observation interval the activity being carried out is noted down in this proforma. Say for example, the observation interval is 0.5 minute, so after every half minute, occurring activity is noted and an entry is made in the corresponding column (point or roster). From the length of observation interval and number of entries in each column, time duration of each work element is calculated. Length of observation interval depends upon the speed of work and the length of work cycle. In forestry work an observation interval of 15 seconds (25/100 min) is customary for work with speedy tools and machines. But if the same operations are being carried out with hand tools and the work cycle time is long enough, the observation interval can be increased to 30 seconds (50/100 min) or even 1 minute.

The prerequisites for the use of multimoment are that the observation points should strictly be adhered to. Each activity must exactly be noted on a prefixed moment, when needle of stop watch crosses the interval mark, irrespective of the fact that a short and relatively less important work element was being performed. The multimoment method is based on the principle of chance and randomization without personal bias.

Advantages of multimoment techniques:

- + One work study man can observe many workers and machines at the same time which is very often needed in forestry work studies.
- + Easy to learn, even a beginner using a short observation interval of 25/100 minute and with little practice can have a sure command.
- + Short work elements are representatively recorded.

Break points between two work elements come across under the law of probability and only in very few cases together with the observation moment. This is an important source of error in other time study techniques, but has no importance in multimoment.

A simple stop-watch and if need be an ordinary wrist-watch with big seconds arm is enough.

Disadvantages:

The work sequence cannot be reconstructed.

With quick changing of place the work study man can make a mistake.

Recording mistakes can only be discovered at the end of work cycle only in the checking column.

Multimoment techniques are suited best when:

- One time study man needs to observe many workers or machines at the same time.
- Many short work elements (under 25/100 min) cannot have a chance to be recorded.

In the course of the investigation under consideration time studies were carried out by multimoment time study method with an observation interval of 1 minute. This length of observation interval was chosen in view of the work being purely manual with sufficiently long work cycles and extensive nature of the study.

Fig.20: TIME STUDIES

Study Level ----- Party Size ----- Nos. of Workers -----
 Forest Division ----- Date ----- Temperature -----
 Range ----- Recorded by ----- Rain -----
 Comptt. No. ----- Interval ----- min ----- Clouds ----- Form No. -----

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Tree No./ Spp.	Tree	Work Cycle Time	Prep.	Oper.	Person Delay	Walk	Felling	Handling	Debranching	Firewood Conver.	Measuring	Cross cut.	V. N.	Tree Features	Check	
1		Work Cycle Begins (Time)													DBH cm	Point Cal.
2															Length m	Point Given
3															MD cm	Diff. Point
4															Vol. m ³	Diff. %
		Points														
		Minutes														
		Tot. Min														

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Other study means were a time study board, writing material and time study proforms. At the observation point, activities of the workers were observed and entered as points in the columns of the corresponding work elements on the time study proforma (Fig. 20)

Number and species of the tree felled and converted by the workers was also noted down. DBH and length of trees was measured during numeration of the crop, so these figures were later on transferred to the time study proforma.

Each day the time of start of work (start of preparation) and close of work (end of preparation) was also recorded along with the duration of breaks. Other general informations about the site and the workers were also taken down.

At the end of each days work, the work cycles were checked for their accuracy by comparing the multimoment points given and the points calculated. Work cycles with a difference of more than 5 % between the points given and points calculated were rejected.

Sum of the multimoment points in the columns of each work element were changed to their respective time value in minutes by dividing them with work party size.

The actual experiment covered 60 days of field work for recording of data on time, work results and heart rate of workers engaged in tree felling and conversion as detailed below:

D a t e s		No. of Days
From	To	
22.09.1984	04.10.1984	13
28.11.1984	17.12.1984	20
17.01.1985	12.02.1984	27
Total		60

The breaks in the study were mainly because of the request of workers to give them time for the extraction of converted timber and firewood and were also necessary for the research staff to visit their families and to organize themselves for the next phase. The time of training of workers in the new work methods and use of improved tools is not included in this period.

The average daily work duration remained about 5 hours and 18 min. The time of breaks made on personal grounds, as for the collection of dry firewood etc. during work is not included in this period.

At the average the workers appeared on work at about 9.00 a.m. and closed the work at about 2.40 p.m. This work duration is very short even though the conditions to start the work earlier and to continue working late in the afternoon were very suitable.

Given below are some of the main reasons for reduced daily work hours.

- High physical workload and high energy demands of timber harvesting work which the workers cannot keep up longer, because of poor nutrition.

- Majority of workers do not carry any lunch with them, which is another cause of energy deficit during work.
- Workers always work in parties and do not set on for work until the party is complete, or even if during work a worker cannot continue further on personal grounds the others also join him and work for the day is closed.
- Before coming to work and after work, the workers attend to their personal engagements, such as milking and feeding of cows and collection of fodder and firewood etc.

4.3.3 Measurement of Work Result

At the end of each days work, the work result in the form of volume of timber and firewood, with respect to each tree was recorded. Each timber piece and regular piece of firewood was measured for its average mid. dia. and length and its volume calculated with Hubers formula.

Irregular pieces of firewood were weighed with the help of a spring balance of 50 kg capacity up to an accuracy of 0.5 kg. The following procedure was adopted to convert kilograms of firewood into cubic meters (solid):

Small samples of fresh firewood being representative with respect to size and species were removed for determining their green density. These samples were cleaned of the saw dust and immediately sealed in the already weighed polythene bags and brought to the headquarters. Green density of these samples was calculated by mercury displacement method (KOLLMANN and COTE, 1968) with the use of Amsler Valometer. The density figures of firewood were based on the average of three samples for each species and came out to be as 1038 kg/m³ for shisham and 1150 kg/m³ for mulberry, respectively. The inverse of these density values

gave the volume in m^3/kg of firewood, which came out to be as $0.0009633 \text{ m}^3/\text{kg}$ firewood of shisham and $0.0008695 \text{ m}^3/\text{kg}$ firewood of mulberry, respectively. The weight of firewood in kilograms was multiplied with these figures to get the quantity of firewood in m^3 in each tree for both the species. Timber and firewood volume for each tree was calculated separately as well as summed up together to get the total tree volume.

The area gave about 217 trees/ha with an average tree to tree distance of about 7 m. The details of these trees is given in the tables 14 and 15.

In all there were 351 trees of mulberry and shisham felled and converted during the experiment (table 14). These trees had an average DBH of 27.4 cm with a large variation ranging between 13 - 72 cm. This is because of crop being uneven-aged and a mixture of mulberry and shisham.

The number of mulberry trees felled and converted was 226 with an average DBH of 24.3 cm, which ranged between 13 and 46 cm. Although the mulberry trees were even-aged, but this larger variation in DBH was mainly because of suppression and lopping of trees for sericulture.

The number of shisham trees included in the experiment was 125 with an average DBH of 32.9 cm, with minimum and maximum limits of 13 and 72 cm. The higher average DBH and large DBH variation in shisham was mainly because of shisham trees consisted of different age classes.

Table 14: Particulars of trees felled and converted with conventional (Level-I) and improved tools (Level-II).

Species	No.of Trees	Av.DBH (Min- Max) cm	Av.Tree Vol. m ³	Av.Timber Vol./ Tree m ³	Av.No. of timber pieces	Av.Timber Piece Vol. m ³	Av.Fire- wood vol/tree m ³	Av.Fire- wood percenta tree
M + S	351	27.4 (13-72)	0.691	0.417	3.03	0.103	0.274	40
M	226	24.3 (13-46)	0.388	0.214	2.89	0.066	0.174	45
S	125	32.9 (13-72)	1.232	0.778	3.28	0.174	0.454	37

M stands for mulberry

S stands for shisham

Species-wise the mulberry trees because of their smaller size had a less average tree volume than shisham. The smaller timber piece volume in mulberry is because of shorter timber pieces cut in lengths not more than 2 m. The higher percentage of firewood in mulberry is because of smaller size of the trees.

The table 15 shows the details of trees felled and converted by different work party sizes in both the study levels. The number of mulberry trees felled and converted remained mostly higher than shisham and this was due to the composition of tree crop. The area was clear felled and no selective cutting was possible to keep the number of mulberry and shisham trees similar in all party sizes. Moreover the number of total trees (mulberry + shisham) felled and converted by different work party sizes was different. It was attempted that the minimum observations for each party size should be in between 40-50, which has been achieved.

But in Level-I studies in the work party sizes of 2 and 3 persons the number of trees felled and converted remained higher. This is because that in the beginning of experiment and for the work party size of 2 and 3 person the observations on heart-rate were recorded with the help of pulse meter, which did not work well. Later on more number of trees were felled and converted with these party sizes to repeat the heart rate observations by manual means.

Table 15: Details of statistics on the trees felled and converted with conventional (Level-I) and improved tools (Level-II) and in different work party sizes.

Work Party Sizes (Persons)	Species	Level-I			Level-II		
		No. of trees	DBH cm		No. of trees	DBH cm	
			Average	standard deviation		Average	standard deviation
2	M	58	23.4	± 6.2	26	23.6	± 6.4
	S	20	34.3	± 17.2	23	31.8	± 14.5
	M+S	78	26.2	± 11.4	49	27.5	± 11.6
3	M	59	23.1	± 6.1	32	26.2	± 7.8
	S	19	36.4	± 14.1	23	32.2	± 16.5
	M+S	78	26.4	± 10.4	55	28.7	± 12.4
4	M	36	25.6	± 6.2	15	26.6	± 5.6
	S	6	38.7	± 20.6	34	31.6	± 15.3
	M+S	42	27.4	± 10.3	49	30.0	± 13.2
Total	M	153	23.8	± 6.2	73	25.3	± 6.9
	S	45	34.9	± 17.1	80	31.8	± 15.2
	M+S	198	26.4	± 10.9	153	28.7	± 12.4

4.4 RECORDING OF HEART RATE

4.4.1 Resting Heart-Rate

The heart rate of workers in the state of rest was taken down every morning before the start of work. Resting heart rate is important for the calculation of average and average maximum working pulse for the individual workers and for work party sizes both in Level-I and II observations. The workers were asked to take rest for 10 (in Level-I) to 15 (in Level-II) minutes in chair sitting position either on a bench made out of branches or on the timber logs. All the workers were smokers and smoked cigarettes while on way to work. They covered a distance of about 2 (in Level-I) and 5 (in Level-II) km to attend work. During resting period they were not allowed to smoke. On the expiry of rest period, the resting heart rate of each worker was measured by counting the pulse beats over a minute at radial artery in the wrist.

4.4.2 Study of Heart Rate during Work

Heart rate measurement were made on the workers while carrying out felling and conversion of mulberry and shisham trees both with conventional (Level-I) and improved tools (Level-II) and in different work party sizes. The heart rate studies were carried out parallel to the time studies (BOMBOSCH, 1984) and the object of making observations on heart rate was to see the effect of improved tools and work party sizes on the physical workload.

At the start of the studies, heart rate monitoring was carried out with the use of photo-electric cell (Kettler Pulse + Time Meter) in a manner of multimoment, with an observation interval of 1 minute. Right in the initial stages of the study it was realized that the heart rate informations given by the photo-

Fig. 21: HEART RATE MANUAL

Study Level	Party Size	Nos. of Workers
Forest Division	Date	Temperature
Range	Recorded by	Rain
Comptt. No.	Interval	Clouds
	min.	Form No.

[illegible][illegible]

electric cell are not reliable. Therefore, the further heart rate studies were carried out by manual means.

Observation on the manual measurement of heart rate was carried out by feeling the pulse beats at carotid artery near Adams apple when the worker was doing a heavy job or at radial artery in the wrist when a worker was at rest or working at a higher level where the time keeper could not easily reach. Time of 11 pulse beats was recorded with the "HEUER" microsplit electronic stop-watches, systematically in the manner of multimoment with an observation interval of 3 minutes and according to the work element being performed by the workers and entered on the proforma (Fig. 21). Mostly one time keeper took the heart rate measurements of two workers alternately after every 1 1/2 minute.

The time of 11 pulse beats was changed to the heart rate as number of heart beats/min by keeping 600 as numerator and time of 11 pulse beats in seconds as denominator.

4.5 SPECIAL INVESTIGATIONS

4.5.1 Studies under Maximum Work Stress

Incentives, especially the system of payment have got a strong influence on the workers performance. Therefore, in the following main study, it was feared that the production results with conventional and improved tools may be biased due to the following reasons:

- In Study Level-I, the workers worked on piece-rate, but in Study Level-II, the workers were paid on time-rate due to the reason already explained. So there remained a big motivational difference between the two study levels. In Sweden monthly pay system for forest workers, resulted into a reduction in labour productivity (AGER, 1981).

- In the course of experiment it was realized that inspite of many advantages of new tools the workers always felt challenged and tried to prove the worth of their tools and methods by putting extra effort in comparison to work with improved tools.

To have a bias free comparison of two types of tools and methods it was thought necessary to repeat observation on a small scale under an incentive which not only eliminates the bias due to difference of wage system but also because of attitude of workers towards improved tools. The new and equal incentive was that a certain number of trees was fixed which appeared to be the job of 3 - 4 hours and the workers were asked to do felling and conversion of these trees, under the condition that the work will be closed for the day as soon as these trees are finished. This proved to be a very powerful motivation and the workers worked under maximum and equal stress for both the methods.

For this purpose 12 trees 6 each of mulburry and shisham were chosen. Attempt was made to keep the 6 trees of each species in 3 pairs and a pair presenting a different DBH. One member of each pair of each species was taken to make 2 groups of 6 trees each (3 mulburry + 3 shisham). This procedure was adopted to keep the two tree groups identical in tree parameters as far as possible (Table 16).

The experiment covered two days. On each day one group of 6 trees was worked with a work party size of the same three workers. On first day they worked with conventional tools and methods and on the second day with improved tools and methods. The heart-rate and the work result were measured in the same way as described earlier. In time studies only the observation interval was reduced from 1 minute to 15 seconds. As the workers worked at maximum work stress therefore, the technical labour productivity will present maximum figures, far higher than the average, but a good and bias free comparison of tools and work methods.

Table 16: Details of mulburry and shisham trees felled and converted with conventional and improved tools under maximum work stress

Species	DBH of trees (cm)		Average DBH (cm)	
	Level-I	Level-II	Level-I	Level-II
mulburry	25	25	31	30
"	32	30		
"	36	35		
shisham	21	21	31	30
"	28	25		
"	43	44		

4.5.2 Comparison of Crosscut Saws

A small experiment was also performed to compare the maximum cross-cutting efficiency (cm^2/min) of peg-tooth and raker-tooth (1:4) cross-cut saws in cutting of mulburry and shisham. Before carrying out such observation both the saws were given proper sharpening and setting. The workers who were included in the experiment were quite fresh and had not worked before for the day. Freshly cut mulburry and shisham stems of about 32 cm diameter were chosen for this purpose. One end of these stems was raised by placing a billet underneath and fixed properly to avoid movements during cutting. The workers alternately cut about 3 - 4 cm thick discs from the raised ends of these stems of each species in half bending body posture. Two cuts each for mulburry and shisham were made with both types of saws. Time taken in the completion of each cut was recorded by stop-watch and average diameter of the cross-face was also measured. Moreover, the number of full saw strokes for completing the cut was also counted.

4.6 ANALYSIS OF DATA

4.6.1 Organization of Data

The information recorded during field experiment were classified into two data sets:

- Data on time and technical labour productivity and
- Data on physical workload (heart rate).

The influence on the dependent variables as well as the differences between data sub-sets were tested. The dependent variables in the first data set were the times and technical labour productivity and in the second data set was the heart rate. The data sub-sets can be seen from the Fig. 22. The entire data material was classified according to the criteria of

- tools (Study Level)
- work party size
- tree species

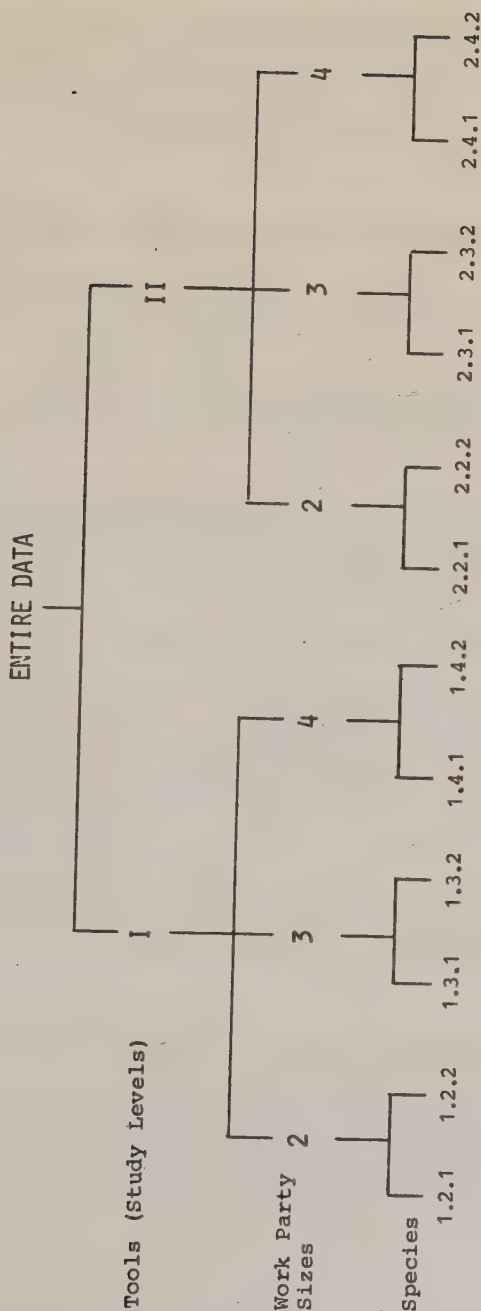
in an hierarchical manner. These data sub-sets provided the basis for the statistical evaluations.

4.6.2 Statistical Procedures

The statistical analysis of data comprised of:

- calculation of simple statistical values (basic statistics) for different data sets,
- testing of relationship within the data sets,
- testing of difference between the means of different data sets.

Fig.22: Grouping of Data



Figures in the lowest tier present the project titles. Each figure comprises of three digits, first denotes the study level, second the work party size and the third, the tree species. Number 1 stands for mulberry and number 2 stands for shisham.

Basic statistics on data sets provided information about the number of observations, sum, mean, variance, standard deviation, coefficient of variation, standard error of mean, confidence interval (lower and upper limit), skewness and kurtosis for different variables.

These values characterized data sets only in one dimension.

To see the interdependence of variables, the random relationship between a given dependent variable (Y-variable) and one or more independent variables (influencing factors, x-variables) was tested. In such situations multiple regression and in this case linear regression was used.

This procedure is designed to calculate a least squares multiple linear regression on a predetermined sets of variables. The general form of regression model is:

$$Y = b_0 + b_1.x_1 + b_2.x_2 + + b_i.x_i + \text{error}$$

Where Y is the dependent variable, x_1 , x_2 and x_i are the independent variables and b_1 , b_2 and b_i are the regression coefficients. In step-wise regression analysis the variable having an F value larger than the F-to-delete is entered in the model. This procedure is repeated with the remaining variables. This process of adding and deleting is continued until all the variables in the model have F values larger than the F-to-deleted and all the variables not in the model have F values smaller than F-to-enter.

The print-out gives the number and names of dependent and independent variables, with tolerance limit and correlation matrix. Step No. Zero gives the numbers and names of independent variables with the values of F and partial correlation. The analysis of variance table in the last step, gives the value of R-squared (coefficient of determination), regression coefficients for the

variables added in the regression model and the value of regression constant.

The limit of tolerance and confidence interval in all statistical analysis remained 0.0001 and 95 %, respectively.

The question whether a difference between the means of corresponding variables from two data sets, e.g. between the mean TLP from study Level-I and II, is significant or not, can be answered by the two-sample t-test.

This procedure is designed to see whether the means of two samples drawn from a normal population having the same variance are equal. The data is entered into the data base created by Basic Statistics and Data Manipulation (BSDM) (ANONYMOUS, 1982). The subfile routine of BSDM is used to create two subfiles as X and Y. Each subfile corresponds to one sample. The Degree of freedom in this case is equal to the sum of observations of X and Y minus 2. In Null-hypothesis it is presumed that the means of X and Y are equal. When calculated value of "t" is higher than the tabulated value of "t" at a given probability level, the Null-hypothesis is rejected. That means there is a significant difference in the averages of X and Y. If the calculated value of "t" is smaller than the tabulated value, no significant difference between the sample means exists.

The majority of the statistical procedures mentioned was conducted with the help of a desk-computer HP 9817 A series 200 and standard software.

4.6.3 Data on Time and Technical Labour Productivity

For the statistical procedures the data in the form of a single matrix comprising of 30 variables and 351 observations (Fig. 23) was fed to the computer. One observation represented the data on one tree.

The variable No. 1 - 3 presents basic informations. The variables from No. 4 - 8 describe the tree parameters related to harvesting the variables from No. 9 - 13 give the work results according to harvested timber quantity with respect to number of pieces and volume.

The variables from No. 14 - 23 give the time demands of different work elements, measured with the help of time studies. These work elements together make a work cycle and are listed as under:

Variable No. in

<u>Data Matrix</u>	<u>Work element</u>	
14	Preparation	} Delay Times
15	Operational Delay	
16	Personal Delay	
17	Walk	} Effective Times
18	Felling	
19	Hang-up	
20	Debranching	
21	Firewood Conversion	
22	Measuring	
23	Cross-Cutting	

Delay times are the times that come across irregularly and are almost independent of tree parameters. For the purpose of time studies, the delay times were recorded for each tree. For data input these however, were equally distributed.

From the times of work elements the following "work times" were constituted:

- Effective time (variable No. 24) = sum of variables 17 to 23,
- Delay time (variable No. 25) = sum of variables 14 to 16,
- Total work time (variable No. 26) = sum of variables 14 to 23.

Fig

Fig.23: Data Matrix on Tree Parameters, Time and TLP

Serial No. (1)	Comptt. No. (2)	Tree No. (3)	Species (4)	DBH cm (5)	Height m (6)	No. of Branches (7)	Lean° (8)	No. of Pieces (9)	Timber Vol. m³ (10)

Av. Piece Vol. m³ (11)	Firewood Vol. m³ (12)	T. Tree Vol. m³ (13)	Preparation min (14)	Operational Delay min (15)	Personal Delay min (16)	Walk min (17)	Felling min (18)	Hang-up min (19)	Debranching min (20)

Firewood Convers. min (21)	Measuring min (22)	Cross-cutting min (23)	Effective Time min (24)	Delay Time min (25)	T. Work Time min (26)	TLP Timber (27)	TLP Firewood (28)	TLP Effective Time (29)	TLP T. Work Time (30)

The data on work results and times provided the basis for the calculation of Technical Labour Productivity (TLP).

TLP for each work cycles was calculated by keeping 60 as numerator and time in min/m³ of production and work party size as denominator:

$$\text{TLP} = \frac{60}{\text{min/m}^3 \times \text{work party size}} = \text{m}^3/\text{man hour}$$

The following TLP-values have been differentiated:

Var. 27: TLP-Timber

60

$$\begin{aligned} & \text{Cross-cutting time (min/m}^3\text{) of timber} \times \text{work party size} \\ &= \text{m}^3 \text{ of timber/man hour} \end{aligned}$$

Var. 28: TLP-Firewood

60

$$\begin{aligned} & \text{Firewood Conversion time (min/m}^3\text{)} \times \text{work party size} \\ &= \text{m}^3 \text{ of firewood/man hour} \end{aligned}$$

Var. 29: TLP-Effective Time

60

$$\begin{aligned} & \text{Effective time (min/m}^3\text{) of timber} + \text{firewood} \times \text{work Party size} \\ &= \text{m}^3 \text{ of timber} + \text{firewood/man hour} \end{aligned}$$

Var. 30: TLP-Total Work Time

60

$$\begin{aligned} & \text{Tot. Work time (min/m}^3\text{) of timber} + \text{firewood} \times \text{work Party Size} \\ &= \text{m}^3 \text{ of timber} + \text{firewood/man hour} \end{aligned}$$

The above expressions of TLP will be useful in the detailed comparison of productivity results with conventional and improved tools in different work party sizes.

To investigate the influences (=independent variables) on time consumption and technical labour productivity for each study level the following regression analysis were carried out:

Dependent Variables

Independent Variables

Effective Time	}	= f (DBH, height, branches, Tot. Tree Vol.)
Tot. Work Time		

Significance of difference of means of effective time and total work time/tree between the two study levels was tested graphically. Two superimposing graphs each for study Level-I and II were plotted between the independent variable of tree volume and dependent variables of effective and total work time/tree along with the confidence limits. When the confidence limits of the two superimposed graphs showed an overlap less than 2/3, the difference was significant.

As to TLP the following multiple regressions were analysed:

Dependent Variables

Independent Variables

TLP Timber	}	= f (species, DBH, height, No. of branches, No. of timber pieces, timber vol., average piece volume, firewood volume, total tree volume)
TLP Firewood		
TLP Effective Time		
TLP Tot. Work Time		

4.6.4 Data on Heart Rate

The data on the heart rate of workers measured manually during work was fed to the computer in the form of a matrix (Fig. 24) comprising of 20 variables and more than 4000 observations. The meaning of the variables is as follows:

- Variables from No. 1 to 7 give general informations about stand and species, tree parameters and the workers.
- Variables from No. 8 to 18 give the total pulse (total heart rate) of the workers recorded during work with respect to different work elements in a work cycle of tree felling and conversion. Zero entries in these columns mean no observations.
- Variable No. 19 is the time of the day in round hours for correlating the heart rate of workers with the day time.
- Variable No. 20 concerns the resting heart rate of the worker recorded each day before the start of work.

The different heart rate parameters are defined as follows:

- Resting heart rate (Resting pulse): It is the heart rate of a worker measured in the state of rest before the start of work.
- Total Pulse: Is that pulse or heart rate of a worker which he attains during work. It is the sum of resting heart rate (resting pulse) and working pulse.
- Working Pulse: It is the rise in the heart rate of a worker during work above his resting heart rate. Working pulse is equal to total pulse minus resting heart rate.

Fig.24: Data Matrix on Heart Rate

SL No. (1)	Comptt. No. (2)	Tree No. (3)	Spp. (4)	DBH cm (5)	Worker No. (6)	Party Size (7)	Prep. (8)	Oper. Delay (9)	Pers. Delay (10)
Walk (11)	Fell- (12)	Hang-up (13)	Debran (14)	F. Wood Conver. (15)	Measur- ing (16)	Cross-cut (17)	Distu- rban (18)	Time (19)	RHR (20)
1	157	180	1	13	1	2	0	0	107
0	131	0	124	115	0	0	0	11	82
2	157	180	1	13	1	2	0	0	0
0	0	0	0	113	0	0	0	11	82
3	157	180	1	13	1	2	0	0	0
0	0	0	0	119	0	0	0	11	82
4	157	180	1	13	3	2	0	0	93
0	0	0	0	0	0	0	0	11	87
5	157	180	1	13	3	2	0	0	91
0	0	0	0	0	0	0	0	11	87
6	157	180	1	13	3	2	0	0	88
0	0	0	0	0	0	0	0	11	87
7	157	180	1	13	3	2	0	0	85
0	0	0	0	0	0	0	0	11	87
8	157	180	1	13	3	2	0	0	86
0	0	0	0	0	0	0	0	11	87
9	156	203	1	19	1	2	0	0	70
0	91	0	113	0	0	104	0	13	82
10	156	203	1	19	1	2	0	0	90
0	0	0	106	0	0	113	0	13	82
11	156	203	1	19	1	2	0	0	0
0	0	0	102	0	0	0	0	13	82
12	156	203	1	19	3	2	0	0	93
0	133	0	113	0	0	118	0	13	87
13	156	203	1	19	3	2	0	0	0
0	0	0	105	0	0	128	0	13	87
14	156	203	1	19	3	2	0	0	0
0	0	0	103	0	0	0	0	13	87
15	156	203	1	19	3	2	0	0	0
0	0	0	126	0	0	0	0	13	87

Heart rate values of worker No. 1 and 2, during felling and conversion of tree No. 180 and 203. Zero in heart rate columns means no observations.

From the data matrix on the heart rate of workers the following total pulse and working pulse parameters were calculated:

- Study Levels: It is an overall average calculated according to study levels and is based on the average of individual worker for each work element in a work cycle, for all the work cycles of a study level together.
- Work elements: It is an overall average calculated according to each work element of a work cycle and is based on the individual heart rate values of workers for all the work cycles in a study level.
- Work party sizes: It is an overall average calculated according to work party sizes in each study level and is based on the individual heart rate values for all the work elements of all the work cycles for a work party size.
- Individual workers: It is an overall average calculated according to individual worker in a study level and is based on the individual heart rate values of a worker for all the work elements of all the work cycles and for all the work party sizes in a study level together.
- Effective time: It is an overall average of heart rate values for effective time work elements in a work cycle and is calculated according to study levels, work party sizes and individual workers.
- Maximum: It is an overall average of maximum heart rate values attained for each work element and is also calculated for individual work party sizes and all the work party sizes in a study level together.

- Maximum effective time: It is an overall average of maximum heart rate values attained for each effective time work element and is also calculated for individual work party sizes and all the work party sizes in a study level together.

For the statistical test, i.e. test on the significance of difference between means and investigation of relation between variables, "t"-test and multiple regression analysis were used as already described in the preceding chapter.

5 RESULTS

5.1 TIME STUDY RESULTS

The time study results given in the tables 17 and 18 present the corrected values of total work time and effective time per 1 cbm tree volume (timber + firewood solid) in felling and conversion of mulberry and shisham trees with conventional (Level-I) and improved tools (Level-II). Corrected figures of times has been used for the purpose of comparison of tools because normal averages did not give a good idea of performance of tools due to differences in the sizes of trees between the two study levels. Moreover, the results of the multiple linear regression analysis showed that tree volume was the strongest determinant of work times than DBH. These results are for a work party size of 3 persons.

5.1.1 Study Levels and Work Times

Total Work Time

As shown by table 17, the corrected values of total work time in felling and conversion of mulberry and shisham trees against a tree volume of 1 m³ with conventional (Level-I) and improved tools (Level-II) remained as 72.37 and 60.04 min, respectively. Improved tools caused a reduction of 12.33 min (17 %) in the total work time/m³ of tree volume in comparison to conventional tools.

The total work time in the felling and conversion of mulberry was as 93.60 and 78.78 min for work with conventional and improved tools, respectively. The improved tools gave a total work time saving of 14.82 min (15.8 %) as compared to conventional tools.

Table 17: Corrected values of total work time/m³ of tree volume in felling and conversion of mulberry and shisham trees with conventional (Level-I) and improved tools (Level-II)

Species	Level-I	Level-II	Decrease for Level-II	
	Total Work Time (min)		min	%
mulberry + shisham	72.37	60.04	12.33	17.0
mulberry	93.60	78.78	14.82	15.8
shisham	63.24	55.30	7.94	12.6

For shisham the total work time/m³ of tree volume was the least both for work with conventional and improved tools in comparison to mulberry. For work with conventional tools (Level-I) the total work time remained as 63.24 min against 55.30 minutes with improved tools (Level-II). Improved tools gave a total work time saving of 7.94 min (12.6 %) per m³ of shisham.

Effective Time

As shown by table 18 the corrected values of effective time/m³ of tree volume remained 49.45 and 42.77 min in felling and conversion of mulberry and shisham trees with conventional (Level-I) and improved tools (Level-II), respectively. Improved tools gave an effective time saving of 6.68 min (13.5 %) per m³ of tree volume.

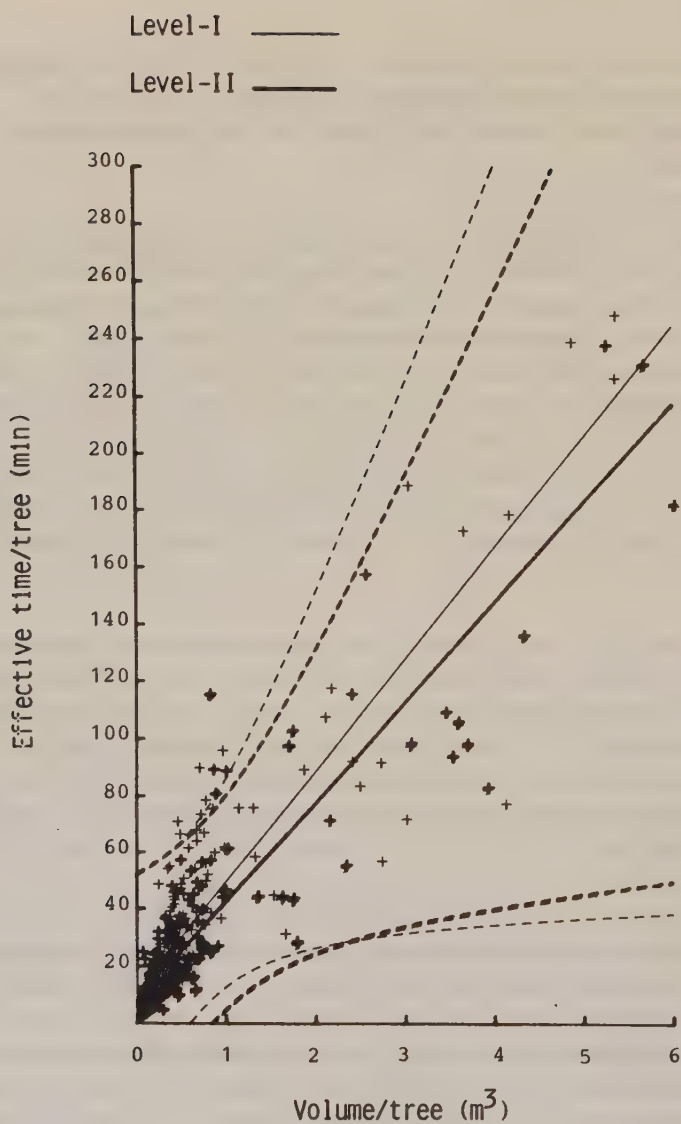


Fig.25: Relationship between effective time/tree and tree volume in felling and conversion of mulberry and shisham with conventional (Level-I) and improved tools (Level-II)

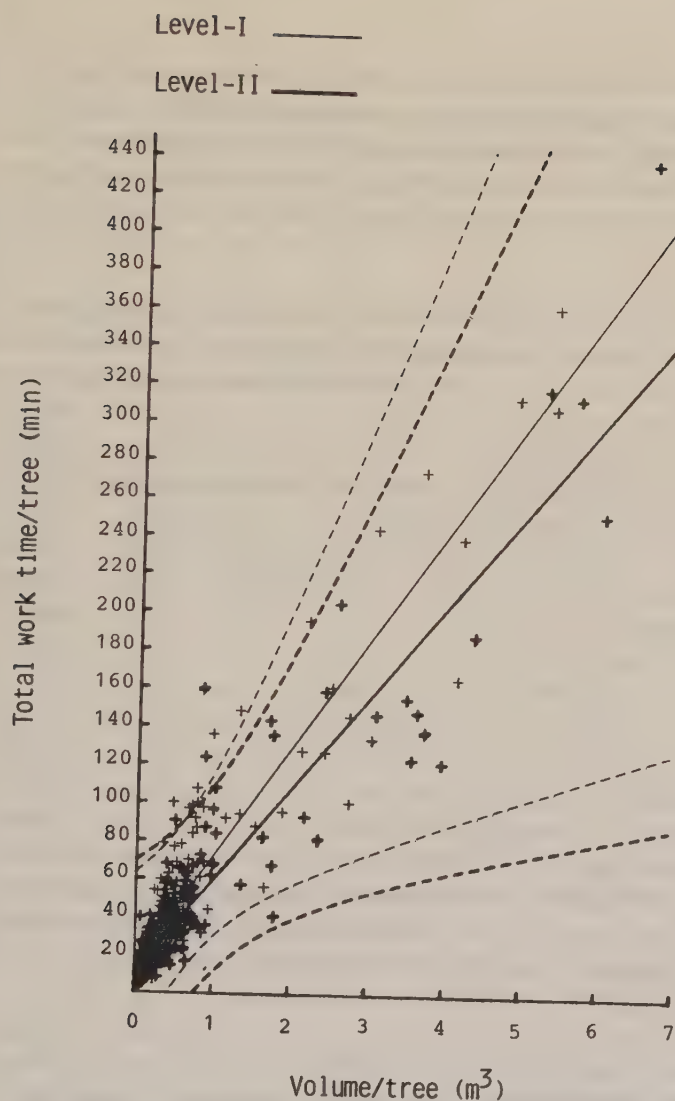


Fig.26: Relationship between total work time/tree and tree Volume in felling and conversion of mulberry and shisham with conventional (Level-I) and improved tools (Level-II)

The effective time was the highest in felling and conversion of mulberry trees in comparison to shisham and came out to be as 65.79 and 57.62 min for conventional (Level-I) and improved tools (Level-II), respectively. Improved tools gave an effective time saving of 8.17 min (12.4 %) per m³ tree volume of mulberry.

Table 18: Corrected values of effective time/m³ of tree volume in felling and conversion of mulberry and shisham trees with conventional (Level-I) and improved tools (Level-II)

Species	Level-I	Level-II	Decrease for Level-II	
	Effective Time (min)		min	%
mulberry + shisham	49.45	42.77	6.68	13.5
mulberry	65.79	57.62	8.17	12.4
shisham	42.54	39.25	3.29	7.7

In felling and conversion of shisham trees the effective time/m³ of tree volume with both types of tools remained the minimum and was 42.54 and 39.25 min for conventional and improved tools, respectively. Improved tools gave an effective time saving of 3.29 min (7.7 %) per m³ tree volume of shisham.

The difference in the total work time and effective time between traditional and improved tools was tested graphically. Superimposing graphs between total work time, effective time and tree volume for conventional (Level-I) and improved tools (Level-II) were drawn along with the confidence limits (Fig. 25 and 26). As the overlap of confidence limits in each graph is more than 2/3, therefore the reduction in the total work time and effective

time/tree for work with improved tools in comparison to conventional tools remained insignificant. With other words, to prove a possibly significant difference between traditional and improved tools a much larger amount of observations would be required. The results obtained here merely indicate a tendency for improved tools being more effective.

The share of effective time as percentage of total work time remained higher in case of improved tools (Level-II), values of 71.2 (mulberry and shisham together), 73.1 (mulberry) and 71.0 % (shisham) has been found. In felling and conversion of mulberry and shisham together and mulberry and shisham alone with conventional tools (Level-I) the share of effective time remained as 68.3, 70.3 and 67.3 % of the work time, respectively. Higher effective time means less delay times which reflects the less physical workload experienced by the workers when working with improved tools.

5.1.2 Study Levels and Tree Times

In a work cycle of tree felling and conversion there were 10 work elements involved. These work elements along with their time shares as averages/tree in minutes for delay time work elements (1-3) and as corrected values min/m^3 of tree volume for effective time work elements (5-10) are given in table 19.

Table 19: Distribution of times of different work elements in a work cycle of tree felling and conversion with conventional (Level-I) and improved tools (Level-II) for both mulberry and shisham.

Work Elements	Level-I	Level-II	Change for Level-II
	minutes/tree		%
Average values			
1. Preparation	0.81	1.87	+ 130.9
2. Operational Delay	0.95	0.45	- 52.6
3. Personal Delay	14.25	12.21	- 14.4
4. Walk	0.67	0.67	0
Corrected values:			
5. Felling	7.85	7.61	- 3.1
6. Hang-up	0.39	0.13	- 66.7
7. Debranching	4.27	2.57	- 39.8
8. Firewood Conversion	20.74	20.35	- 1.9
9. Measuring	0.74	0.74	0
10. Cross-cutting	14.79	10.75	- 27.3

Delay Time Work Elements

As shown by the above table the share of preparation time in an average work cycle remained as 0.81 and 1.87 min for conventional tools (Level-I) and improved tools (Level-II), respectively. Preparation time remained by about 130.9 % higher in case of improved tools. There was not much to do in preparation to work with the conventional tools. The workers simply put their cycles on the compartment road, took their axes and saws and moved into the stand.

The preparation to work with improved tools involved the unloading of the tools from the vehicle (the improved tools were daily transported to the work site by the research staff of P.F.I on a vehicle), removing of protective covers of the saws, fixing of handles to the raker-tooth crosscut saws, taking of wedges, canthook and tying of belts with pockets to their waists. Similarly at the end of work the reverse of this sequence of events was repeated. These all activities posed a higher time demand for preparation to work with improved tools.

Operational delay was mainly the time spent in fixing of loosened tool handles of the axes and cross-cut saws. Operational delay time decreased by about 52.6 % in case of improved tools. This was because of better handles provided with raker-tooth cross-cut saws, which could be tightly fixed to the saw with the screwing mechanism. These handles got loose very rarely and if so could very quickly be tightened by simple turning the handle to the right hand side. While in contrast to it, the handles of pegtooth cross-cut saws were pieces of branches passed through the round eye made out of iron sheet, fixed by rivets to the each end of saws. These types of handles got loose very frequently, partly because of their design and partly due to poor quality of handles and also took much time in their refixing.

Time of personal delays remained by about 14.4 % less for improved tools than conventional tools. The reason for this can be the less physical workload resulting into less need for rest breaks and also greater choices of tools when working with improved tools. The conventional tools only comprised of axes and cross-cut saws. When a worker working with axe could finish his work earlier than the two doing crosscutting then he waited for the other two to finish the work, so that they could start on the next tree. But in case of improved tools if the operation of firewood conversion with bill-hook and bow saws was finished the worker instead of waiting, joined the others in cross-cutting of smaller diameters with bow-saw.

Time of walk from tree to tree was 0.67 min/tree for both the work methods. This was not because the trees were equally spaced and workers walked with a constant speed, but as a principle the walktime is averaged and then added to the work cycles. Because the time of walk depends upon the distance between the trees and has got no relation with the tree parameters and tools.

Effective Time Work Elements

Tree felling time remained 7.85 and 7.61 min/m³ with conventional and improved tools, respectively and showed a decrease of 3.1 % with improved tools as compared to conventional tools. Although some more sub-elements of work were involved in felling with improved tools and methods, as more careful clearing of work place for sawing in kneeling or sitting position, cutting of climbers, removal of bark at the position of felling cuts, fixing of felling direction, making of felling cuts and use of wedges.

Hang-up time with improved tools and methods was reduced by about 66.7 %. This was only because of almost a complete control over the direction of fall. Whatso-ever hang-up of trees occurred with improved methods was not of serious nature. Only some of the branches remained stuck-up in the other trees, which were released without difficulty.

Debranching time decreased by about 39.8 % with improved tools. Bowsaw either worked by one man or two men remained a dominant tool in this operation. Axe and raker-tooth crosscut saw was also used in cramped conditions and for thicker branches of shisham. While in case of conventional tools axe dominated the debranching work which is decidedly less efficient in cutting as compared to bowsaw.

Firewood conversion time per m³ of tree volume decreased slightly by about 1.9 % in case of improved tools. In contrast to it the average time demand for firewood conversion/tree remained by

about 18 % higher with improved tools. Because of the use of bill-hooks for cutting of branches upto 3 - 4 cm dia and thicker branches with the use of bowsaws. So the workers had to change the tools frequently according to the size of branches, which caused loss of time. Another reason for higher time demand in firewood conversion/tree in Level-II studies was the short training duration of workers to work with improved tools and methods. Though the workers very quickly picked up the new methods in 14 days training, this period of training remained insufficient to change their habits of work. They always forgot to use the wedges at the proper time or axe for driving in the wedges to carry with. This resulted into the loss of time either in searching for axe or releasing the saw binds. Axe was the only tool for firewood conversion with conventional methods. It could cut all sizes of branches and made the firewood conversion operation faster because the time loss due to change of tools, driving in of wedges or releasing the saw binds was out of question.

Measuring time with both the work methods remained equal and was 0.74 min/m³ of tree vol.

Cross-cutting time was 27.3 % less with improved tools, because of better cutting of raker-tooth cross-cut saw and use of wedges at the proper time.

Table 20 gives the percentage distribution of different work element times in an average work cycle of tree felling and conversion with conventional (Level-I) and improved tools (Level-II) irrespective of work party sizes and tree species.

Table 20: Distribution of different work elements times as percentage of total work time and effective time/tree for work with conventional tools (Level-I) and improved tools (Level-II).

Work Elements	Level-I			Level-II		
	% of Total Work Time	% of Effec. tive Time	% of Delay Time	% of Total Work Time	% of Effec- tive Time	% of Delay Time
1. Preparation	1.6		5.0	3.8		13.0
2. Operational Delay	2.0		6.2	1.0		3.4
3. Personal Delay	28.4		88.8	24.4		83.6
4. Walk	1.4	2.1		1.4	2.0	
5. Felling	10.7	15.7		13.0	18.4	
6. Hang-up	0.8	1.2		0.2	0.3	
7. Debranching	5.9	8.7		4.0	5.6	
8. Firewood Conversion	28.4	41.7		33.8	47.7	
9. Measuring	1.2	1.7		1.4	2.0	
10. Cross-cutting	19.9	28.9		17.0	24.0	

As shown by table 20, for work with conventional tools (Level-I) and among the effective time work elements the biggest time intensive operation was firewood conversion, which demanded 28.4 and 41.7 % of the total work time and effective time, respectively. Next to firewood conversion was cross-cutting which had a time share of 19.9 % of the total work time and 28.9 % of the effective time. The work of tree felling with conventional tools needed 10.7 % of the total work time and 15.7 % of the effective time. The share of debranching, walk, measuring and hang-up remained as 5.9, 1.4, 1.2 and 0.8 % of total work time and 8.7, 2.1, 1.7 and 1.2 % of the effective time, respectively.

Among the delay time work elements the biggest share was for personal delays as 28.4 and 88.8 % of the total work time and delay time, respectively. The share of operational delay and preparation remained as 2.0 and 1.6 % of the total work time and 6.2 and 5.0 % of the delay time, respectively.

The order of time demands of different work elements with improved tools (Level-II) remained the same as for conventional tools. Some of the values showed an increase, while the others decreased in comparison to conventional tools.

HILF and ECKERT (1957) in the "Tree and Volume Time Tables" for pines reported the effective time demands in minutes for some important work elements in felling and conversion of pines of 30 cm DBH with hand tools and in two mens work party size (table 21) in the Federal Republic of Germany.

Table 21: Comparison of effective times for some important work elements in tree felling and conversion between Pakistan and Federal Republik of Germany.

Work Elements	mulberry and shisham (Pakistan)	Pines (Fed. Rep. Germ.)	Increase for Pine
	Effective Time (min/tree)		
Felling	6.5	11.6	+ 5.1
Hang-up	0.11	0.8	+ 0.69
Debranching	2.0	10.8	+ 8.8
Measuring and Cross-cutting	9.2	4.0	- 5.2

These times in comparison to work with improved tools in felling and conversion of mulberry and shisham trees of an average DBH of 29 cm and with a work party size of 3 persons in Changa Manga Plantation in Pakistan, remained higher by 5.1, 0.69 and 8.8 min for the work of felling, hang-up and debranching of trees. While in measuring and cross-cutting, the time demands for pine trees remained 5.2 min less than mulberry and shisham trees. These differences in the effective times of different work elements are mainly because of different nature of tree species and work requirements.

For a just comparison of performance of workers and tools in timber harvesting, it is essential that the tree species, work requirements and work conditions should be identical.

5.1.3 Work Party Sizes and Work Times

The results on the effect of work party sizes on work times are given in the table 22.

Table 22: Total work time and effective time per tree in felling and conversion of mulberry and shisham trees with different work party sizes.

Work Party Sizes (Persons)	Average DBH of Trees (cm)	Total Work Time	Effective Time	Percentage Effective Time
		Min/Tree		
2	26.9	59.1	44.7	76
3	27.4	47.6	32.1	67
4	28.8	42.4	26.6	60

The values given in the above table are average figures both for conventional tools (Level-I) and improved tools (Level-II). As shown by this table, the total work time remained as 59.1, 47.6 and 42.4 min/tree for work party sizes of 2, 3 and 4 persons respectively, with a gradual decrease with the increasing work party size, even though the DBH of trees had an increasing trend in higher work party sizes. Effective time was 44.7, 32.1 and 25.6 min/tree for the party size of 2, 3 and 4 persons respectively, and showed a similar decreasing trend with the increasing work party size (Fig. 27). Share of effective time remained as 76, 67 and 60 % of total work time per tree for a work party size of 2, 3 and 4 persons, respectively. Decrease in effective time/tree with increasing work party size means an increase in delay time/tree with increasing work party size.

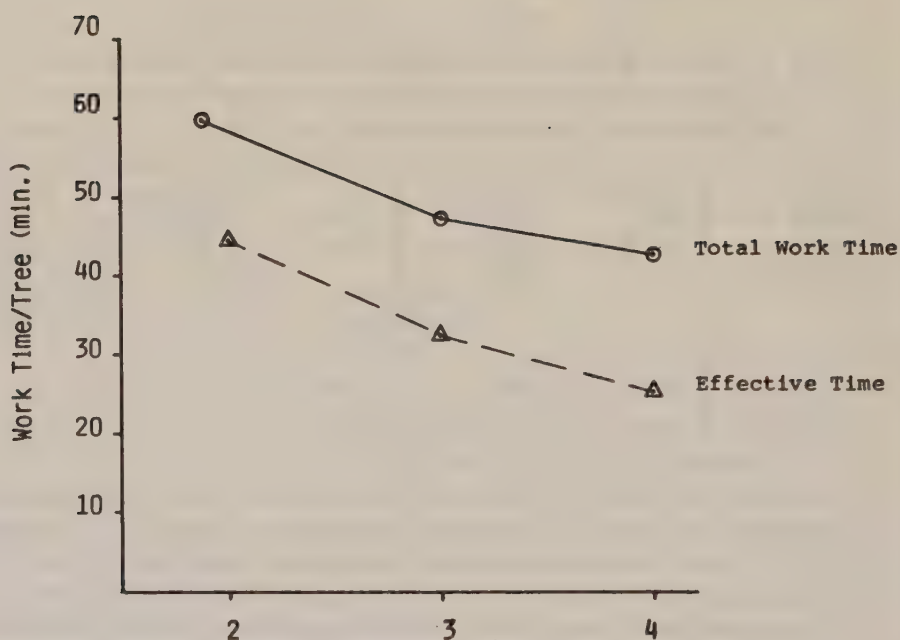


Fig.27: Work Party Sizes (persons)

Effect of work party size on the total
work time and effective time per tree

Table 23 shows the effect of tools on the total work time and effective time/tree in a work cycle.

Table 23: Effect of conventional (Level-I) and improved tools (Level-II) and different work party sizes on the average total work time and effective time/tree in felling and conversion of mulberry and shisham trees.

Work Party Sizes (Persons)	Study Levels	Average DBH of Trees (cm)	Total Work Time	Effective Time
			Min/Tree	
2	I	26.2	56.9	43.3
	II	27.5	62.6	47.0
3	I	26.4	48.3	32.1
	II	28.7	46.6	32.2
4	I	24.4	43.7	23.2
	II	30.0	41.3	27.6

The average total work time/tree with improved tools (Level-II) showed a decrease as compared to conventional tools for work parties of 3 and 4 persons, but it showed an increase for the work party size of 2 persons. The decrease in total work time/tree with improved tools in case of work party sizes of 3 and 4 persons was mainly because of better performance of improved tools even though the tree sizes were comparatively higher. Increase in total work time/tree with improved tools in work party size of 2 persons does not find any reason, except the higher tree size as compared to conventional tools.

For work with improved tools, the average effective time/tree remained higher for work party sizes of 2 and 4 persons and nearly equal for a work party size of 3 persons as compared with conventional tools.

Table 24 shows the percentage of effective time in an average work cycle time for different tools and work parties. The proportion of effective time in a work cycle remained higher for improved tools (Level-II) by about 3 % and 26 % for party sizes of 3 and 4 persons respectively, while it decreased by about 1 % for a party size of 2 persons. The decrease in effective time/tree was more steep with conventional tools (Level-I) as compared to improved (Level-II), with increasing work party sizes (Fig. 28).

Table 24: Effective time as percentage of total work time/tree in felling and conversion of mulberry and shisham trees with conventional tools (Level-I) and improved tools (Level-II) and different work party sizes.

Work Party Sizes (Persons)	Level-I	Level-II	Change for Level-II %
	Effective Time as % age of Total Work Time/Tree		
2	76	75	- 1
3	67	69	+ 3
4	53	67	+ 26

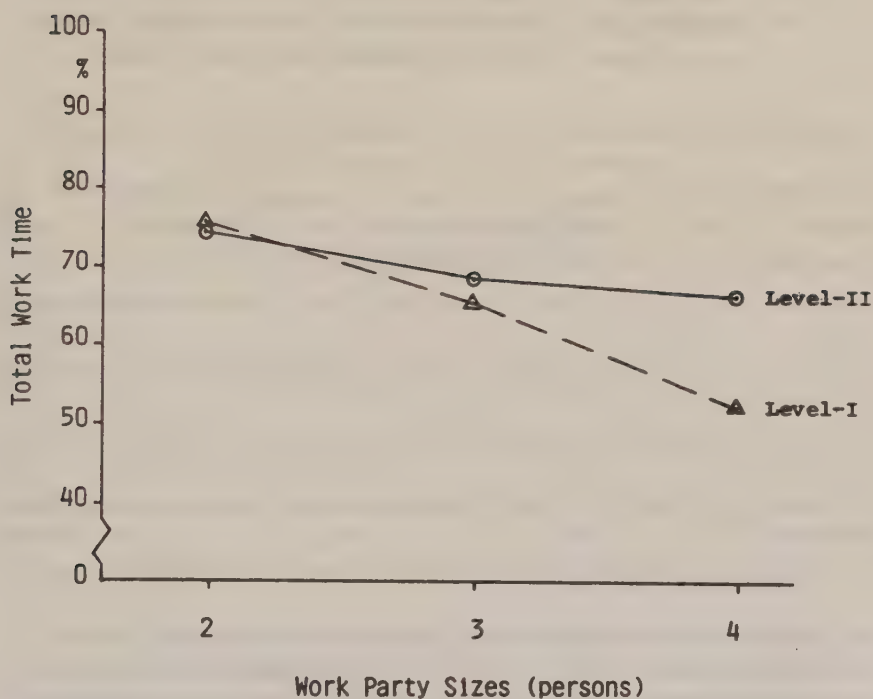


Fig.28: Distribution of effective time/tree as % of total work time for work party sizes and study levels

The decrease in effective time/tree is due to an increase in delay times/tree with the increasing work party sizes (table 25).

Table 25: Percentage of delay time with respect of total work time/tree in felling and conversion of mulberry and shisham trees with conventional (Level-I) and improved tools (Level-II) and different work party sizes.

Work Party Sizes (Persons)	Level-I	Level-II	Change for Level-II %
	Delay Time as % age of Total Work Time/Tree		
2	24	25	+ 4
3	33	31	- 6
4	47	33	- 30
Average	35	30	- 14

The delay times in a work cycle comprised of preparation, operational delays and personal delays. Preparation time is only at the start and end of work and operational delays come across by chance and independent of work party sizes. Therefore the reason for an increase in delay times with increasing work party sizes is mainly because of increase in personal delay time.

Table 26 giving the percentage of personal delay time in an average work cycle time in different work party sizes.

Table 26: Personal delay time as percentage of total work time/ tree in felling and conversion of mulberry and shisham trees with conventional (Level-I) and improved tools (Level-II) in different work party sizes.

Work Party Sizes (Persons)	Level-I	Level-II	Change for Level-II %
	Personal Delay Time as % age of Total Work Time/Tree		
2	19	20	+ 5
3	31	26	- 16
4	45	29	- 36
Average	32	25	- 22

For improved tools (Level-II), the personal delay time remained by about 22 % less as compared to conventional tools (Level-I). Improved tools (Level-II) also resulted into a lower personal delay time by about 16 % and 36 %, for party sizes of 3 and 4 persons respectively, but personal delay time increased by about 5 % for a work party size of 2 persons.

5.1.4 Tree Parameters and Work Times

Multiple linear regression analysis was carried out to see the influence of different tree parameters on the effective and total work time/tree. Table 27 and Fig. 29 show the results of this analysis between the dependent variables of effective and total work time/tree and different independent variables of tree parameters.

Effective and total work time/tree remained very strongly and positively correlated with values of R^2 (Coefficient of Determination) as high as 0.819 and 0.879 respectively, to the tree parameters of DBH, No. of branches/tree and total tree volume (timber + firewood) in Level-I studies (conventional tools). Effective and total work time/tree likewise, remained strongly and positively correlated with values of R^2 as high as 0.835 and 0.848 respectively to the tree parameters as No. of branches/tree and tree volume in Level-II studies (improved tools). In Level-I studies DBH also showed its effect on the effective and total work time/tree, but in Level-II studies, it did not appear as a factor influencing different work times. Which means that work time demand with improved tools was not under the significant influence of tree diameter.

Among different tree parameters the tree volume had the strongest influence on effective and total work time/tree as depicted by highest values of the product of $b_i \times S_i$ (Regression coefficient $\times$ Standard Deviation) both for study Level-I and II. Next important factors were DBH in case of Level-I and No. of branches/tree both for Level-I and II as depicted by the value of product of $b_i \times S_i$.

Influence of these tree parameters on the total work time and effective time/tree was positive and highly significant as shown by very high F-values.

Table 27: Results of regression analysis between different work times (dependent variables) and tree parameters (independent variables) in felling and conversion of mulberry and shisham trees.

Study Levels	Regression No.	Dependent Variables	Independent Variables	b_i	S_i	$b_i \times S_i$	R^2	F-value
1	2	3	4	5	6	7	8	9
I	I. 1	Effective Time	DBH	0.620	± 10.872	6.741	0.819	*** 293.95
			Branches	1.744	± 2.188	3.816		
			Tree vol.	28.852	± 0.891	25.707		
	I. 2	Total Work Time	DBH	0.872	± 10.872	9.480	0.879	*** 471.57
			Branches	2.416	± 2.188	5.286		
			Tree vol.	42.712	± 0.891	38.056		
II	II. 1	Effective Time	Branches	1.994	± 2.412	4.810	0.835	*** 380.68
			Tree vol.	32.009	± 1.174	35.579		
	II. 2	Total Work Time	Branches	2.227	± 2.412	5.372	0.848	*** 418.40
			Tree vol.	44.829	± 1.174	52.629		

The data on multiple linear regression analysis between different work times and tree parameters according to species are given in the tables 28 and 29 and Fig. 30.

Fig.29: Regression Analysis

$$\begin{array}{l} \text{Effective Time} \\ \text{Tot. Work Time} \end{array} = f(\text{DBH, Height, Branches, Tot. Tree Vol.})$$

Study Levels	Regression Equations	R ²
I	1. Effective Time = $-5.143 + 0.620 \cdot \text{DBH} + 1.744 \cdot \text{Branches} + 28.852 \cdot \text{Tree Vol.}$	0.819
	2. Tot. Work Time = $-6.409 + 0.872 \cdot \text{DBH} + 2.416 \cdot \text{Branches} + 42.712 \cdot \text{Tree Vol.}$	0.879
II	1. Effective Time = $4.454 + 1.994 \cdot \text{Branches} + 32.009 \cdot \text{Tree Vol.}$	0.835
	2. Tot. Work Time = $8.173 + 2.227 \cdot \text{Branches} + 44.829 \cdot \text{Tree Vol.}$	0.848

Confidence limit = 95 %

Table 28: Results of regression analysis between different work times (dependent variables) and tree parameters (Independent variables) in felling and conversion of mulberry

Study levels	Regression No.	Dependent Variable	Independent Variable	b_i	S_i	$b_i \times S_i$	R^2	F-value
1	2	3	4	5	6	7	8	9
I	I. 1.1	Effective Time	Height	0.682	± 3.890	2.553	0.659	***
				1.134	± 1.868	2.118		95.95
			Tree Vol.	50.049	± 0.259	12.963		***
	I. 1.2	Total Work Time	Height	0.794	± 3.890	3.089	0.739	140.93
				2.259	± 1.868	4.220		
			Tree Vol.	68.555	± 0.259	17.756		
II	II. 1.1	Effective Time	DBH	-0.928	± 6.880	6.385	0.700	***
			Tree Vol.	70.165	± 0.339	23.786		82.01
	II. 1.2	Total Work Time	Tree Vol.	70.814	± 0.339	24.006	0.699	*** 164.63

* significant at 95 % level

** significant at 98 % level

*** significant at 99 % level

Table 29: Results of regression analysis between different work times (dependent variables) and tree parameters (Independent variables) in felling and conversion of shisham

Study levels	Regression No.	Dependent Variable	Independent Variable	b_i	S_i	$b_i \times s_i$	R^2	F-value
1	2	3	4	5	6	7	8	9
I	I. 2.1	Effective Time	Height Tree vol.	-2.267 44.676	<u>+4.698</u> <u>+1.541</u>	10.650 68.846	0.872	*** 146
	I. 2.2	Total Work Time	Tree vol.	57.863	<u>+1.541</u>	89.167	0.912	*** 456
II	II. 2.1	Effective Time	Tree vol.	35.079	<u>+1.522</u>	53.390	0.862	*** 485
	II. 2.2	Total Work Time	Tree vol.	48.383	<u>+1.522</u>	73.639	0.871	*** 528

* significant at 95 % level
 ** significant at 98 % level
 *** significant at 99 % level

Fig.30: Regression Analysis

$$\begin{array}{l} \text{Effective Time} \\ \text{Tot. Work Time} \end{array} = f(\text{DBH, Height, Branches, Tree Vol.})$$

Study Level	Species	Regression Equations	R ²
I	1. mulberry	1.1 Effective time = $-2.248 + 0.682 * \text{Height} + 1.134 * \text{Branches} + 50.049 * \text{Tree Vol.}$	0.659
		1.2 Tot. Work Time = $-1.285 + 0.794 * \text{Height} + 2.259 * \text{Branches} + 68.555 * \text{Tree Vol.}$	0.739
	2. shisham	2.1 Effective Time = $34.695 - 2.267 * \text{Height} + 44.676 * \text{tree Vol.}$	0.872
		2.2 Tot. Work Time = $5.380 + 57.863 * \text{Tree Vol.}$	0.912
II	1. mulberry	1.1 Effective Time = $20.063 - 0.928 * \text{DBH} + 70.165 * \text{Tree Vol.}$	0.700
		1.2 Tot. Work Time = $7.316 + 70.814 * \text{Tree Vol.}$	0.699
	2. shisham	2.1 Effective Time = $4.104 + 35.079 * \text{Tree Vol.}$	0.862
		2.2 Tot. Work Time = $6.933 + 48.383 * \text{Tree Vol.}$	0.871

Confidence limit = 95 %

Tree volume universally appeared in all regression equations and was the strongest determinant especially in shisham for different time demands as depicted by the highest values of $b_1 \times s_1$. Next significant tree parameters coming up as determinant of effective and total work time/tree was No. of branches/tree and tree height, mostly in case of mulberry worked by conventional tools. DBH only appeared once as a significant factor affecting effective time demand in case of mulberry worked with improved tools.

The data on regression analysis given in the tables 28 and 29 showed that the improved tools were not sensitive to the tree parameters other than the tree volume in respect of work time demands as effective and total work time/tree.

5.1.5 Tree Parameters and Tree Times

The results of multiple linear regression analysis between dependent variables of tree times and independent variables of tree parameters are given in the table 30 and Fig. 31. In this analysis only the important tree times like felling, firewood conversion and cross-cutting were taken, while the tree parameters included in the regression were DBH, Height No. of branches, No. of timber pieces, timber volume, average timber piece volume, firewood volume and tree volume (timber + firewood). Results of the regression analysis showed that all tree times remained positively and strongly correlated to the tree parameters appearing in regression equations as depicted by high values of R^2 both for studies with conventional (Level-I) and improved tools (Level-II).

In Level-I studies, tree volume was the only determinant of felling time, but in Level-II studies, timber volume/tree followed by DBH were the factors affecting felling.

Table 30: Results of regression analysis between the time of some important work elements (dependent variables) and tree parameters (Independent variables) in felling and conversion of mulberry and shisham trees.

Study levels	Regression No.	Dependent Variable	Independent Variable	b_i	S_i	$b_i x s_i$	R^2	F- value
1	2	3	4	5	6	7	8	9
I	I. 1	Felling	Tree vol.	6.353	± 0.891	5.661	0.688	*** 433.30
	I. 2	Firewood Conversion	Branches DBH Av. Piece vol. Firewood vol.	1.122 0.252 32.267 29.446	± 2.188 ± 10.872 ± 0.110 ± 0.304	2.455 2.740 3.549 8.952	0.848	*** 215.57
	I. 3	Cross- cutting	No./Pieces Timber vol.	1.112 16.342	± 2.045 ± 0.618	2.274 10.099	0.721	*** 253.21
II	II. 1	Felling	DBH Timber vol.	-0.217 4.643	± 12.393 ± 0.796	2.689 3.696	0.739	*** 211.79
	II. 2	Firewood convers.	Branches Av. Piece vol. Timber vol. Tree vol.	1.222 -32.266 -18.792 31.183	± 0.403 ± 0.145 ± 0.796 ± 1.174	0.493 4.679 14.958 36.609	0.809	*** 124.82
	II. 3	Cross- cutting	Av. Piece vol. Timber vol.	-28.176 20.340	± 0.145 ± 0.796	4.086 16.191	0.806	*** 311.84

Fig. 31: Regression Analysis

Felling
Firewood
Conversion
Cross-cutting

= f (species, DBH, Height, Branches, No. of Pieces, Timber vol.,
Av. Piece vol., F. Wood vol., Tot. Tree vol.)

STUDY LEVELS	Regression Equation	R ²
I. 1	Felling = 1.501 + 6.353 x Tot. Tree vol.	0.688
I. 2	Firewood = 0.613 + 0.252 x DBH + 1.122 x Branches Conversion + 32.267 x Av. Piece vol. + 29.446 x F. Wood volume	0.848
I. 3	Cross-cutting = 0.272 + 1.112 x No. of Pieces + 16.342 x Timber vol.	0.721
II. 1	Felling = 0.188 - 0.217 x DBH + 4.643 x Timber vol.	0.739
II. 2	Firewood = 8.827 + 1.222 x Branches - 18.792 x Timber vol. Conversion - 32.266 x Av. Piece vol. + 31.183 x Tot. Tree vol.	0.809
II. 3	Cross-cutting = 2.302 + 20.340 x timber vol. - 28.176 x Av. Piece vol.	0.806

There appeared four tree parameters affecting time demand for firewood conversion in both the study levels. In study Level-I firewood volume/tree remained the strongest determinant of firewood conversion time as depicted by the product of $b_i \times s_i$, followed by the average timber piece volume, DBH and No. of branches/tree. In Level-II studies, the tree volume appeared as a parameter having a strong influence on firewood conversion time, followed by timber volume, average timber piece volume and No. of branches/tree as depicted by the product of $b_i \times s_i$ for each set of variables.

In cross-cutting, timber volume/tree came up as the strongest determinant of cross-cutting time in both the study levels. Next to it was the No. of timber pieces/tree in study Level-I and average timber piece volume in study Level-II.

In Level-II studies timber volume/tree appeared as a tree parameter strongly affecting different tree times as felling firewood conversion and cross-cutting, probably because of trees being comparatively thicker and had more timber outturn than Level-I studies (conventional tools).

The effect of different tree parameters appearing in the regression equations in Level-I studies was highly significant and positive, as depicted by very high "F" values. While in Level-II studies, the effect although was highly significant, but of DBH on felling time, average timber piece volume and timber volume on firewood conversion time and average timber piece volume on cross-cutting time had a negative effect.

5.2 TECHNICAL LABOUR PRODUCTIVITY

5.2.1 Study Levels and Technical Labour Productivity

The results relative to average technical labour productivity in timber harvesting as $\text{m}^3/\text{man hour}$, with conventional (Level-I) and improved tools (Level-II) are given in the table 31. The technical labour productivity figures in this table present the average for different productivity variables/tree in each study level, irrespective of tree species and work party sizes.

Table 31: Average technical labour productivity ($\text{m}^3/\text{man}/\text{hour}$) in felling and conversion of trees (mulberry + shisham) with conventional (Level-I) and improved tools (Level-II).

Productivity Variable	Level-I	Level-II	Percentage Increase for Level-II
	TLP = m ³ /man hour		
1. Total volume/ Total Work Time	0.249	0.307	+ 23 ***
2. Total volume/ Effective Time	0.368	0.447	+ 21 ***
3. Timber volume/ Cross-cutting Time	0.807	1.126	+ 40 ***
4. Firewood volume/ Firewood conv. Time	0.484	0.500	+ 3

* Significant at 95 % level

** Significant at 98 % level

*** Significant at 99 % level.

Different productivity variables are the technical labour productivity in total volume production (timber + firewood) with respect to total work time and effective time, timber and firewood production with respect to cross-cutting and firewood conversion time, respectively.

As shown by the table 31, improved tools (Level-II) caused a highly significant increase of 23, 21 and 40 % in the productivity variables as compared to conventional (Level-I) tools.

TLP - Total Volume/Total Work Time

The average technical labour productivity in total volume production (timber + firewood) with respect to total work time came out to be as 0.249 and 0.307 m³/man hour for conventional (Level-I) and improved tools (Level-II), respectively. In other words about 241 man minutes were needed to produce 1 m³ of timber and firewood with conventional tools and 195 man minutes with improved tools. This showed that improved tools gave a time saving of about 46 man minutes/m³ of productivity.

The increase in the average technical labour productivity with respect to total volume and total work time for work with improved tools was about 23 % and highly significant.

TLP - Total Volume/Effective Time

The average technical labour productivity (timber + firewood) with respect to effective time came out to be as 0.368 and 0.447 m³ man hour for conventional tools (Level-I) and improved tools (Level-II), respectively.

In other words about 163 man minutes of effective time were needed to produce 1m³ of timber and firewood with conventional tools and 134 man minutes with improved tools. This showed that the improved

tools were quicker in tree felling and conversion and gave an effective time saving of about 29 man minutes/m³ of productivity.

The increase in technical labour productivity with respect to effective time in case of improved tools was about 21 % and highly significant. This increase in technical labour productivity in Level-II studies and with respect to effective time was by about 2 % less than the technical labour productivity with respect to total work time. The reason for this was about 5 % increase in effective time per work cycle with improved tools as compared to conventional tools.

TLP - Timber Volume/Cross-cutting Time

The average technical labour productivity in timber production was calculated to see the efficiency of improved tools and methods in cross-cutting of mulberry and shisham trees and is denoted as volume of timber produced with respect to cross-cutting time. The average technical labour productivity in timber production was 0.807 and 1.126 m³/man hour with conventional tools (Level-I) and improved tools (Level-II), respectively.

This means that it required about 74 man minute to cross-cut 1 m³ of timber with conventional tools and 53 man minute with improved tools. Improved tools caused a highly significant increase of 40 % in technical labour productivity of timber with respect to cross-cutting time.

The highly significant increase in technical labour productivity (timber + firewood) with respect to total work time and effective time and timber production with respect to cross-cut time is only because of training of workers and better performance of improved tools and work methods in comparison to conventional tools and methods.

There are many literature based examples of higher performance of improved tools in tree felling and conversion. Raker-tooth cross-cut saws and bowsaws gave a higher work performance as compared to peg-tooth cross-cut saw and axe (MALETA and SOOD, 1984, LAARMAN et al., 1981, HANSSON et al., 1966). Besides its better cutting, bowsaw is of much advantage over axe with respect to timber losses. ANONYMOUS (1984) reported a wood wasted of 7.7 % in felling of shisham trees with axe in Changa Manga Plantation in Pakistan. The results of studies on the choice of technology in forestry in Philippine (LAARMAN, et al., 1981) showed that the bowsaw is 7 - 11 times less wasteful than axe. Training, improved tools and their proper maintenance resulted into a productivity increase of 15 % (SUMANTRI, 1979) and 33 % (GÜRTAN, 1964) in tree harvesting in Java (Indonesia) and Turkey, respectively.

TLP - Firewood Volume/Firewood Conversion Time

In firewood production the average technical labour productivity with conventional tools (Level-I) and improved tools (Level-II) remained 0.484 and 0.500 m³ (solid)/man hour respectively. Contrary to the expectations, this increase remained insignificant, even though the bowsaw is much efficient in cutting as compared to axe. (MALETA and SOOD, 1984, LAARMANN et al., 1981, HANSSON et al., 1966). In this study bill-hooks and bowsaws did not prove much better than conventional axe in cutting of firewood of mulberry and shisham trees. The following reasons can be accounted for this fact:

- a) Nature of species: Both the tree species felled and converted in this experiment were hardwoods. Shisham showed a staghorn pattern of branching, while in mulberry the crowns were more or less bushy because of lopping for its leaves. Under such situations the work of firewood conversion with bowsaw was somewhat difficult, because for the working of bowsaw the firewood pieces had to be cleaned before being cut. This

accounted for an increase in work time. On the other hand the conventional axe did cutting and removal of small branches in a single operation.

- b) Sizes of firewood : Every piece which was thinner than about 15 cm in diameter and thicker than about 3 cm in diameter was to be converted into firewood. In case of improved tools the branches from 3 to 4 cm in diameter were cut with bill-hook and thicker ones with bowsaw. This work necessitated the frequent change over of tools, which resulted in the wastage of time. The conventional axe was the only tool for cutting of all diameters.
- c) Insufficient training of workers: In two weeks training period though the workers, because of their experience in timber harvesting, picked up the new work methods and use of improved tools very quickly and gave good demonstrations, but this period of training remained insufficient to improve their work habits. When left to work at their own, they mostly forgot to carry all the tools needed for work from one point to the other. This resulted into the loss of time during firewood conversion in the form of saw binds, because there was no axe to drive in the wedge at the proper time and also additional time wastage when the worker returned to the former work place to pick up the axe. This remained more or less a common cause of time loss in almost all other works when working with improved tools.

5.2.2 Tree Species and Technical Labour Productivity

The results on the average technical labour productivity (m^3/man hour) in harvesting of mulberry and shisham trees with conventional (Level-I) and improved tools (Level-II) are given in the table 32. The technical labour productivity figures in this table present the average for different productivity variables/tree of

mulberry and shisham in each study level, irrespective of work party sizes.

Table 32 shows that in case of mulberry, improved tools (Level-II) caused a highly significant increase of 24, 23 and 41 % in the technical labour productivity variables of total volume production with respect to total work time and effective time and timber volume production with respect to cross-cutting time, respectively. While the firewood volume production with respect to firewood conversion time remained almost unchanged. In shisham there occurred a significant decrease of 15, 15 and 23 % in the technical labour productivity variables of total volume production with respect to total work time and effective time and firewood production with respect to firewood conversion time respectively, with improved tools. Only the timber production with respect to cross-cutting time showed an insignificant increase of 6 %.

Technical labour productivity in shisham for all different productivity variables remained higher than mulberry, both with conventional (Level-I) and improved tools (Level-II). This was because of heavy size of trees and higher average timber piece volume in shisham. The average DBH of trees was 33 and 24 cm for shisham and mulberry, respectively and the average timber piece volume remained as 0.174 m³ for shisham and 0.066 m³ for mulberry. The higher timber piece volume in shisham was because of thick timber with lengths normally ranging between 3 - 5 m, while in mulberry timber size was thin with lengths never more than 2 m. Proportion of thick firewood also seemed to be high in shisham because of higher tree diameters.

Table 32: Average technical labour productivity (m³/man hour) in felling and conversion of mulberry and shisham trees.

Species	Productivity Variables	Level-I	Level-II	Percentage increase for Level-II
		TLP = m ³ /man hour		
mulberry	Total Volume/ Total Work Time	0.213	0.265	*** + 24
	Total Volume/ Effective Time	0.314	0.386	*** + 23
	Timber Volume/ Cross-cutting Time	0.757	1.070	*** + 41
	Firewood Volume Firewood Conv. Time	0.418	0.417	0
shisham	Total Volume/ Total Work Time	0.372	0.318	* - 15
	Total Volume/ Effective Time	0.550	0.466	* - 15
	Timber Volume/ Cross-cutting Time	0.977	1.035	+ 6
	Firewood Volume/ Firewood Conv. Time	0.705	0.545	* - 23

* Significant at 95 % level

** Significant at 98 % level

*** Significant at 99 % level.

TLP - Total Volume/Total Work Time

The average technical labour productivity in mulberry with respect to total volume (timber + firewood) and total work time was 0.213 and 0.265 m³/man hour with conventional (Level-I) and improved tools (Level-II), respectively. This means that for mulberry it took about 282 and 226 man minutes of total work time to give 1 m³ (timber + firewood) with conventional (Level-I) and improved tools (Level-II), respectively.

Improved tools and methods proved much faster in total outturn in mulberry and gave a total work time saving of about 56 man minutes/m³ of productivity. Technical labour productivity increase in mulberry with respect to total volume and total work time for improved tools was about 24 % and highly significant.

The average technical labour productivity in shisham with respect to total volume (timber + firewood) and total work time remained as 0.372 and 0.318 m³/man hour for conventional (Level-I) and improved tools (Level-II), respectively. In other words it took about 161 and 189 man minutes of total work time to produce 1 m³ (timber + firewood) with conventional (Level-I) and improved tools (Level-II), respectively. Improved tools did not prove efficient in total outturn in shisham and demanded 28 man minutes more of total work time to produce 1 m³ of timber and firewood, resulting into a significant decrease of 15 % in technical labour productivity.

TLP - Total Volume/Effective Time

The average technical labour productivity in mulberry with respect to total volume (timber + firewood) and effective time was 0.314 and 0.386 m³/man hour with conventional (Level-I) and improved tools (Level-II), respectively. In other words, it required 191 and 155 man minutes of effective time to produce 1 m³ of mulberry timber and firewood with conventional tools (Level-I) and improved

tools (Level-II), respectively. Improved tools (Level-II) gave an effective time saving of 36 man minutes/m³ of total outturn. Efficiency of improved tools (Level-II) is also reflected by a highly significant technical labour productivity increase of 23 % in mulberry.

In shisham the average technical labour productivity with respect to total volume (timber + firewood) and effective time was 0.550 and 0.466 m³/man hour with conventional (Level-I) and improved tools (Level-II), respectively which means that to produce 1 m³ of outturn it required 109 and 129 man minutes of effective time with conventional (Level-I) and improved tools (Level-II), respectively. Improved tools did not prove better in the conversion of shisham trees and required about 20 man minutes more of effective time to produce 1 m³ of timber and firewood. This resulted into a significant decrease of 15 % in the technical labour productivity with improved tools in shisham.

TLP - Timber Volume/Cross-cutting Time

The average technical labour productivity for mulberry with respect to timber volume and cross-cutting time was 0.757 and 1.070 m³/man hour with conventional (Level-I) and improved tools (Level-II), respectively. This shows that it required about 79 and 56 man minutes of cross-cutting time to produce 1 m³ of mulberry timber with conventional (Level-I) and improved tools (Level-II), respectively. Improved tools gave a cross-cutting time saving of 23 man minutes/m³ of mulberry timber. Higher performance of improved tools and methods in cross-cutting of mulberry is also reflected by a highly significant increase of 41 % in timber production with respect to cross-cutting time.

In shisham the average technical labour productivity with respect to timber volume and cross-cutting time came out to be as 0.977 and 1.035 m³/man hour for conventional (Level-I) and improved

tools (Level-II), respectively. It required about 61 and 58 man minutes of cross-cutting time to produce 1 m³ of shisham timber with conventional (Level-I) and improved tools (Level-II), respectively.

Improved tools were slightly faster in cross-cutting of shisham timber and needed about 3 man minutes less to cut 1 m³ of shisham timber than conventional tools. This resulted into an insignificant increase of 6 % in the production of shisham timber with respect to cross-cutting time with improved tools.

TLP - Firewood volume/Firewood Conversion Time

The average technical labour productivity for mulberry with respect to firewood volume and firewood conversion time was 0.418 and 0.417 m³/man hour with conventional tools (Level-I) and improved tools (Level-II), respectively. There was no change in the production of firewood with improved tools as compared with conventional tools.

In shisham the average technical labour productivity in firewood conversion with respect to firewood conversion time remained 0.705 and 0.545 m³/man hour for conventional (Level-I) and improved tools (Level-II), respectively. In other words, it required 85 and 110 man minute of firewood conversion time to produce 1 m³ of firewood with conventional and improved tools, respectively. Improved tools demanded 25 man minutes more than the conventional tools to produce 1 m³ of firewood in case of shisham. Improved tools gave a very poor performance in the conversion of shisham firewood and resulted into a significant decrease of 23 % in technical labour productivity.

The improved tools remained equal to the conventional tools in the production of mulberry firewood, while they behaved very poor in case of shisham as projected by a significant decrease of 23 % in firewood production. The causes of poor performance

of improved tools in the conversion of firewood are already discussed at the end of chapter 5.2.1.

During the course of experiment it was observed that cross-cutting of heavy shisham trees was always hazzardous. Saw binds were frequent due to thick stems and uneven distribution of stress because of kinks and bends. Problem of saw binds was of a more serious nature when working with raker-tooth crosscut saw and even the use of wedges did not help much. The cuts seemed fairly open due to wedging, but the raker-tooth saw remained heavy to move further. The reason seems to be the thicker gauge and narrow and long teeth of raker-tooth crosscut saw. Due to delayed wedging of closing cut, the lateral pressure on the teeth caused them to slightly bend inwards and further cutting produced a narrower kerf, which bound the saw just at the base of teeth. Normally the workers apply wedges when the saw starts getting heavy. But it is advisable to do the wedging well in advance, while cutting with raker-tooth crosscut saw, if the closing of a cut is suspected. A heavy hammer of about 5 kg weight is needed to do wedging in heavy shisham stems, because normal axe proved to be ineffective for this work.

Another reason for the poor performance of improved tools in comparison to conventional tools in cutting of shisham is the heavy and hard nature of its wood. Hardness of wood has a direct influence on the cutting efficiency of the saw. This fact is cleared by the results of a small experiment carried out to determine the maximum cross-cutting efficiency of raker-tooth and peg-tooth crosscut saws in cutting of mulberry and shisham.

Maximum Cross-cutting Efficiency (cm^2/min) of Peg-tooth and Raker-tooth Crosscut Saws.

The results of the experiment on the maximum cross-cutting efficiency (cm^2/min) of peg-tooth and raker-tooth crosscut saws in cutting of mulberry and shisham are given in table 33. The metho-

dology of experiment is detailed in chapter 4.5.2. The average cross-cutting efficiency remained as 429 and 728 cm²/min (cut area) for peg- and raker-tooth saw respectively, in cutting of both mulberry and shisham. Raker-tooth saw was by about 70 % faster as compared to peg-tooth crosscut saw.

For mulberry alone the cross-cutting efficiency of peg and raker-tooth crosscut saw came out to be 363 and 867 cm²/min, respectively. Performance of raker-tooth crosscut saw remained by about 139 % higher in cutting of mulberry.

Cross-cutting efficiency of peg- and raker-tooth crosscut saw was 495 and 589 cm²/min, respectively for cutting of shisham and raker-tooth crosscut saw was only by about 19 % faster in comparison to peg-tooth crosscut saw.

Table 33: Maximum cross-cutting efficiency of peg-tooth and raker-tooth crosscut saws in cutting of mulberry and shisham.

Species	Average cut diameter cm	Average No. of strokes/ min.	Cross-cutting Efficiency cm ² /min.		Percentage Increase for Raker-tooth saw
			Peg-tooth saw	Raker-tooth saw	
mulberry + shisham	32	62	429	728	+ 70
mulberry	33	61	363	867	+ 139
shisham	32	62	495	589	+ 19

Density is a single criterion of wood properties and has got a close correlation with the mechanical behaviour of wood (KOLLMANN and COTE, 1968), such as strength, hardness and resistance to abrasion. These properties of wood also influence the performance of cutting tools. Dense and harder woods are difficult to cut.

Attribute	Species		Percentage increase in shisham
	mulberry	shisham	
Density (Air Dry)* gm/cm ³	0.687	0.819	+ 19
side Hardness (Green) Newtons	4,290	6,270	+ 46

* (Ayaz, 1981)

Shisham wood is by about 19 % more denser (air dry state) and by about 46 % more harder (green state) than mulberry. This difference of strength properties is also reflected in 139 % higher maximum cross-cutting efficiency of raker-tooth crosscut saw in cutting of softer wood of mulberry in comparison to shisham, while raker-tooth crosscut saw was only 19 % faster than peg-tooth crosscut saw in cutting of shisham. In contrast to raker-tooth, peg-tooth crosscut saw proved better in cutting of shisham than mulberry, probably because of its narrow gauge and narrow kerf, which proved faster in cutting of hard and comparatively dry wood of shisham. The probable cause of poor performance of peg-tooth saw in cutting of mulberry is that the inner bark of mulberry trees have got a milky juice, which mixes with the powdery saw dust of the peg-tooth saw, gets stuck to the teeth of the saw and adversely affects the cutting efficiency. On the other hand saw dust in cutting of mulberry with raker-tooth crosscut saw comes out in the form of curled and long flakes and the teeth and kerf remains clean and clear.

Saw-setting Parameters

Depth of the raker in raker-tooth crosscut saw is adjusted according to the density of wood. For hardwoods a raker adjustment of 0.2 - 0.5 mm is recommended (ANONYMOUS, 1970). In this experiment raker was adjusted to 0.3 mm. This adjustment of raker proved optimum for cutting of mulberry depicted by the saw dust in the form of long flakes and smooth and fast cutting with clean cuts. For cutting of shisham this adjustment of raker was probably too high evidenced by poor cutting, powdery saw dust, jumping of saw inside the cut with a ringing sound and uneven surface of the cut faces. Lower adjustment could not be tried because 0.3 mm was the least possible adjustment with the raker adjuster available.

Grain direction in wood also influences the work of cutting tools (KOLLMANN and COTE, 1968). Mulberry is a straight-grain timber while the grain arrangement in shisham is inter-locked (Ahmad and Ayaz, 1970). In raker-tooth crosscut saw cutting teeth cut the wood and rakers chisel out the central uncut portion. The chiseling action of raker is very easy in case the wood is straight-grained (mulberry), because grain direction is parallel to the cutting edge of raker. In the timbers which are not straight-grained (shisham), the grain of wood runs at an angle to the cutting edge and therefore offers increased resistance to the chiseling action of the raker.

5.2.3 Work Party Sizes and Technical Labour Productivity

5.2.3.1 Work party sizes and conventional tools (Level-I)

The results on the average technical labour productivity ($\text{m}^3/\text{man hour}$) in harvesting of mulberry and shisham trees with conventional tools (Level-I) and different work party sizes are given in table 34.

As shown the work party size of 2 persons working with conventional tools remained more productive than the work party sizes of 3 and 4 persons. Technical labour productivity for all productivity variables showed a steady decrease with increasing work party size, except for technical labour productivity variables with respect to total volume and effective time, for work party size of 4 which showed a slight increase over the work party size of 3 persons.

Table 34: Average technical labour productivity ($\text{m}^3/\text{man hour}$) in harvesting of mulberry and shisham trees with conventional tools (Level-I) with different work party sizes.

Productivity Variables	2 Persons	3 Persons	4 Persons
	TLP = $\text{m}^3/\text{man hour}$		
Total volume/ Total Work Time	0.297	0.230	0.195
Total volume/ Effective Time	0.392	0.350	0.357
Timber volume/ Cross-cutting Time	0.812	0.806	0.801
Firewood volume/ Firewood conversion Time	0.549	0.459	0.408

Productivity indexes for all the technical labour productivity variables for the work party sizes of 2 and 3 persons were calculated against the base values of the technical labour productivity variables for the work party size of 4 persons and are given in table 35.

Technical labour productivity indexes for the productivity variable of total volume with respect to total work time were 152 and 118 for the work party size of 2 and 3 persons respectively, against a base value of 100 for the work party size of 4 persons.

Technical labour productivity indexes for the productivity variable of total volume with respect to effective time were 110 and 98 for work party size of 2 and 3 persons, showing a 10 % increase and 2 % decrease respectively, in comparison to work party size of 4 persons.

Table 35: Technical labour productivity indexes in harvesting of mulberry and shisham trees with conventional tools (Level-I) and different work party sizes.

Productivity Variables	2 Persons	3 Persons	4 Persons
	TLP = m ³ /man hour		
Total volume/ Total Work Time	152	118	100
Total volume/ Effective Time	110	98	100
Timber volume/ Cross-cutting Time	101	101	100
Firewood volume/ Firewood conversion Time	135	113	100

Technical labour productivity indexes in timber volume production with respect to cross-cutting time were by about 1 % higher both for the party size of 2 and 3 persons.

In firewood conversion technical labour productivity indexes remained 135 and 113 for the work party size of 2 and 3 persons showing a 35 and 13 % increase respectively, in comparison to work party size of 4 persons.

The following reasons could be accounted for the higher performance of the work party size of 2 persons with conventional tools (Level-I):

- As shown by the time study results the effective time/work cycle decreased with the increasing work party size. Higher effective time for the work party size of 2 persons is one of the reasons for maximum performance with conventional tools.
- In Level-I studies the workers worked on piece-rate. In higher work party sizes, jealousy among the workers was also a cause of time loss. If a worker was not putting much effort in work, the others also slowed down. But in the work party size of 2 persons the element of jealousy was least because both of them remained occupied with work almost equally and therefore, gave maximum performance.

5.2.3.2 Work party sizes and improved tools (Level-II)

The results on the average technical labour productivity ($\text{m}^3/\text{man hour}$) in harvesting of mulberry and shisham tree with improved tools (Level-II) and in different work party sizes are given in table 36.

Values of different technical labour productivity variables showed that the work party size of 3 persons working with improved tools (Level-II) gave a higher technical labour productivity than the work party sizes of 2 and 4 persons, except firewood conversion where work party size of 4 persons gave the best performance followed by work party sizes of 3 and 2 persons.

Table 36: Average technical labour productivity ($\text{m}^3/\text{man hour}$) in harvesting of mulberry and shisham trees with improved tools (Level-II) and different work party sizes.

Productivity Variables	2 Persons	3 Persons	4 Persons
	TLP = $\text{m}^3/\text{man hour}$		
Total volume/ Total Work Time	0.316	0.341	0.261
Total volume/ Effective Time	0.416	0.518	0.400
Timber volume/ Cross-cutting Time	1.228	1.274	0.859
Firewood volume/ Firewood conversion Time	0.453	0.508	0.538

Without firewood conversion the next best work party size in terms of technical labour productivity was of 2 persons.

Productivity indexes for all the technical labour productivity variables for the work party sizes of 2 and 3 persons were calculated by keeping the technical labour productivity values for the work party size of 4 persons as a base. The results are given in table 37.

Table 37: Technical labour productivity indexes in harvesting of mulberry and shisham trees with improved tools (Level-II) and different work party sizes.

Productivity Variables	2 Persons	3 Persons	4 Persons
	Productivity Indexes		
Total volume/ Total Work Time	121	131	100
Total volume/ Effective Time	104	130	100
Timber volume/ Cross-cutting Time	143	148	100
Firewood volume/ Firewood conversion Time	84	94	100

The technical labour productivity indexes for the productivity variable of total volume and total work time were 121 and 131 for the work party size of 2 and 3 persons respectively, against a base value of 100 for the work party size of 4 persons.

Technical labour productivity indexes for the productivity variable of total volume with respect to effective time were 104 and 130 for work party size of 2 and 3 persons.

Technical labour productivity indexes in timber production with respect to cross-cutting time were 143 and 148 for work party size of 2 and 3 persons respectively.

In firewood conversion the work party sizes of 2 and 3 persons gave a poor performance in comparison to the work party size of 4 persons, evidenced by a technical labour productivity indexes of 84 and 94 respectively, against 100 for the work party size of 4 persons.

In case of conventional tools the work party size of 2 persons gave maximum productivity results because of the reasons explained previously. But in case of improved tools the work party size of 3 persons proved to be the optimum in terms of work performance, probably because of the following reasons:

- In Level-II studies the effective time/work cycle also decreased with the increasing work party size. But the trend was not so steep as in case of Level-I. This probably caused the shift of higher productivity in favour of a work party size of 3 persons.
- In Level-I studies, the tools used by each work party were mainly of two kinds, axes and crosscut saw and a work party size of 2 persons gave their optimum utilization. But in Level-II studies, the tools with each work party comprised of axes, bill-hooks, bowsaws, three different types of wedges and a raker-tooth crosscut saw. Therefore, a higher work party size of 3 persons instead of 2 gave their optimum utilization.
- In Level-II studies the workers were paid on time rate and the element of jealousy among the workers in higher work party sizes was not so strong, which resulted into a higher performance of a work party size of 3 persons in contrast to a work party size of 2 persons in Level-I studies paid on piece-rates.

5.2.3.3 Work Party Sizes and Study Levels

The average technical labour productivity ($\text{m}^3/\text{man hour}$) for different productivity variables/tree in felling and conversion of mulberry and shisham trees with conventional tools and improved tools and different work party sizes, along with technical labour productivity increase in percentage with improved tools is given in the table 38.

As shown by this table, the improved tools (Level-II) gave a higher technical labour productivity of varying extent for all productivity variables and work party sizes, except firewood conversion with respect to firewood conversion time in case of work party size of 2 persons, where it decreased by about 17 % with improved tools.

The work party size of 3 persons remained optimum to work with improved tools and gave a highly significant increase of 48 %, 48 % and 58 % in technical labour productivity for the productivity variables of total volume with respect to total work time and effective time and timber volume with respect to cross-cutting time respectively, while the technical labour productivity in firewood conversion with respect to firewood conversion time showed an insignificant increase of 11 %.

In total volume production with respect to total work time and effective time in Level-II studies, the work party size of 4 persons gave a higher performance than the work party size of 2 persons. The increase in technical labour productivity for the above productivity variables remained insignificant with 34 and 12 % respectively for the work party size of 4 persons against an insignificant increase of 6 % each, for the work party size of 2 persons.

Table 38: Technical labour productivity ($\text{m}^3/\text{man hour}$) in felling and conversion of mulberry and shisham trees with conventional (Level-I) and improved tools (Level-II) and in different work party sizes.

Work Party size (Persons)	Productivity Variables	TLP = $\text{m}^3/\text{man hour}$		Percentage increase in Level-II
		Level-I	Level-II	
2	Total volume/ Total Work Time	0.297	0.316	+ 6
	Total volume/ Effective Time	0.392	0.416	+ 6
	Timber volume/ Cross-cutting Time	0.812	1.228	*** + 51
	Firewood volume/ Firewood Conversion Time	0.549	0.453	- 17
3	Total volume/ Total Work Time	0.230	0.341	*** + 48
	Total volume/ Effective Time	0.350	0.518	*** + 48
	Timber volume/ Cross-cutting Time	0.806	1.274	*** + 58
	Firewood volume/ Firewood Conversion Time	0.459	0.508	+ 11
4	Total volume/ Total Work Time	0.195	0.261	+ 34
	Total volume/ Effective Time	0.357	0.400	+ 12
	Timber volume/ Cross-cutting Time	0.801	0.859	+ 7
	Firewood volume/ Firewood Conversion Time	0.408	0.538	+ 32

* Significant at 95 % level

** Significant at 98 % level

*** Significant at 99 % level

In timber volume production with respect to cross-cutting time in Level-II studies the work party size of 2 persons gave a significant technical labour productivity increase of 51 %, while this change remained only 12 % and insignificant in case of work party size of 4 persons.

Technical labour productivity in firewood conversion with respect to firewood conversion time for work with improved tools (Level-II) altered with increasing work party size from - 17 to 11 and 32 % for the work party sizes of 2, 3 and 4 persons respectively. The work party size of 4 persons gave maximum performance. The work party size of 2 persons working with improved tools gave very poor performance in firewood conversion. The changes in technical labour productivity in firewood conversion with all work party sizes remained insignificant.

The reasons for the better performance of a work party size of 3 persons working with improved tools (Level-II) have already been discussed.

5.2.4 Tree Parameters and Technical Labour Productivity

The results of regression analysis between different independent variables of tree parameters such as DBH, Height, No. of Branches, No. of timber pieces, timber volume, average timber piece volume, firewood volume and volume of each tree (timber + firewood) and different dependent variables of technical labour productivity (TLP) with respect to total work time and effective work time/tree, timber and firewood production with respect to cross-cutting and firewood conversion time respectively, collective as well as according to tree species are given in the Fig. 32 to 35 and tables 39 to 44.

5.2.4.1 Conventional Tools (Level-I)

As shown by table 39 different TLP variables for work with conventional tools (Level-I) remained under a highly significant influence of different tree parameters as depicted by very high F-values. However, the correlation remained very weak with very low values of R^2 .

Very weak correlation with highly significant values of F can be somewhat confusing for the readers. But this and even opposite of it can happen due to the fact that the F-values change with the degree of interdependence of X and Y, while the values of R^2 are influenced by the range of dispersion of Y. In the following lines different conditions under which the values of R^2 and F appear in a regression equation are discussed with the help of a simple linear relationship between X (independent variables) and Y (dependent variables):

- When values of F and R^2 are nearly zero or zero. This means that there exists no relationship between X and Y.
- When values of both F and R^2 are high. This shows that the values of Y significantly change with the changing values of X and at the same time the deviations between the actual and corrected values of Y are very less.
- When the values of F are high with low R^2 values. This shows that values of Y change significantly with the changing values of X and the deviations between actual and corrected values of Y are large. Due to this reason the results of regression analysis between trees parameters and TLP variables show very low values of R^2 .
- When the values of F are low with high R^2 values. This means that there is no significant change in Y values with changing values of X and deviations between actual and corrected values of Y are very less.

The causes of low R^2 values can also be due to the following reasons:

- Errors in data recording;
- Some other influencing factors have not been included in the regression equation, for example the work capacity of the individual workers;
- The regression line is not properly fitting for the actual Y values.

Technical labour productivity with respect to total work time was highly and significantly influenced by height of the trees, number of timber pieces/tree and firewood volume produced by each tree. Correlation between these tree parameter and technical labour productivity remained weak with a value of R^2 as 0.235.

Among different tree parameters appearing as highly significant, the height of the trees was the strongest determinant of technical labour productivity with respect to total work time as depicted by the highest value of the product of b_i (regression coefficient) and s_i (standard deviation) as 0.049, followed by firewood volume and No. of timber pieces in each tree with values of $b_i \times s_i$ as 0.024 and 0.021, respectively.

The technical labour productivity with respect to total work time increased with the increasing height and firewood volume/tree, while it decreased with the increasing number of timber pieces/tree as shown by the positive and negative values of regression coefficients, respectively.

Fig.32: Regression Analysis

$$\begin{matrix} \text{TLP T.Work Time} \\ \text{TLP Effect.Time} \\ \text{TLP Timber} \\ \text{TLP Firewood} \end{matrix} = f \begin{matrix} (\text{DBH, Height, No. of Branches, No. of timber pieces,} \\ \text{Timber vol., Av. Timber piece vol., Firewood vol., Tree vol.}) \end{matrix}$$

Regression No.	Regression Equations	R ²	F. Value
I. 1	TLP T.Work Time = 0.133 + 0.010 x Height - 0.010 x No. of Timber pieces + 0.080 x Firewood vol.	0.235	*** 19.96
I. 2	TLP Effect.Time = 0.011 + 0.009 x DBH + 0.013 x Height - 0.014 x Branches - 0.029 x No. of timber pieces - 0.097 x Av. Timber pieces vol.	0.357	*** 21.41
I. 3	TLP Timber = - 0.074 + 0.033 x DBH + 4.609 x Av. Timber piece vol. - 0.642 x Tree vol.	0.209	*** 16.32
I. 4	TLP Firewood = 0.529 + 0.034 x Height - 0.035 x Branches - 0.166 x No. of Timber pieces + 4.886 x Timber vol. - 2.844 x Av. Timber piece vol. + 5.180 x Firewood vol. - 4.601 x Tree vol.	0.536	*** 31.57

Table 39: Influence of different tree parameters on the different dependent variables of technical labour productivity for work with conventional tools (Level-I).

Regr. No. 1	Dependent variables 2	Independent variables 3	b_i 4	s_i 5	$b_i \times s_i$ 6	R^2 7	F-value 8
I. 1	TLP T. Work Time	Height	0.010	± 4.87	0.049	0.235	*** 19.96
		No. of timber pieces	-0.010	± 2.05	0.021		
		Firew. vol.	0.080	± 0.30	0.024		
I. 2	TLP Effect. Time	DBH	0.009	± 10.87	0.098	0.357	*** 21.41
		Height	0.013	± 4.87	0.063		
		Branches	-0.014	± 2.19	0.031		
		No. of timber pieces	-0.029	± 2.05	0.059		
		Av. Piece vol.	-0.097	± 0.11	0.011		
I. 3	TLP Timber	DBH	0.033	± 10.87	0.359	0.201	*** 16.32
		Av. Piece vol.	4.609	± 0.11	0.507		
		Tree vol.	-0.642	± 0.89	0.571		
I. 4	TLP Fire- wood	Height	0.034	± 4.87	0.166	0.536	*** 31.57
		Branches	-0.035	± 2.19	0.077		
		No. of timber pieces	-0.116	± 2.05	0.238		
		Timber vol.	4.886	± 0.62	3.029		
		Av. Piece vol.	-2.844	± 0.11	0.313		
		Firewood vol.	5.180	± 0.30	1.554		
		Tree vol.	-4.061	± 0.89	4.095		

* significant at 95 % level

** significant at 98 % level

*** significant at 99 % level.

Technical labour productivity with respect to effective work time remained under the highly significant influence of such tree parameters as DBH, Height, No. of branches, No. of timber pieces and average timber piece volume. The correlation between these tree parameters and technical labour productivity was weak with a value of R^2 as 0.357. Among different tree parameters appearing as highly significant, the DBH of the trees was the strongest determinant of technical labour productivity with respect to effective work time as depicted by the highest value of $b_i \times s_i$ as 0.098, followed by height, No. of timber pieces, No. of branches and average timber piece volume with the values of $b_i \times s_i$ as 0.063, 0.059, 0.031 and 0.011, respectively.

The effect of DBH and height of the trees on the technical labour productivity variable with respect to effective time was positive, while No. of branches and timber pieces/tree and average timber piece volume had a negative effect on this productivity variable.

Technical labour productivity in timber production with respect to cross-cutting time was highly and significantly influenced by such tree parameters as DBH, average timber piece volume and tree volume. Correlation between these tree parameters and technical labour productivity remained very weak with a low value of R^2 as 0.201. Among different tree parameters appearing as highly significant, total tree volume remained the strongest determinant of technical labour productivity in timber production with respect to cross-cutting time as shown by the highest value of $b_i \times s_i$ as 0.571, followed by average timber piece volume and DBH of the trees with the values of $b_i \times s_i$ as 0.507 and 0.359, respectively. Technical labour productivity in timber with respect to cross-cutting time increased with increasing DBH of trees and average timber piece volume, while it decreased with increasing tree volume as shown by the positive and negative values of regression coefficients, respectively.

Technical labour productivity in firewood production with respect to firewood conversion time remained under the highly significant influence of many tree parameters such as tree height, No. of branches, No. of timber pieces, timber volume, average timber piece volume, firewood volume and tree volume. The correlation between these parameters and technical labour productivity remained strong with the value of R^2 as 0.536. Among different tree parameters appearing in the regression equation, tree volume remained the strongest determinant of technical labour productivity in firewood production with respect to firewood conversion time with the highest value of $b_i \times s_i$ as 4.095, followed by timber volume, firewood volume, average timber piece volume, No. of timber pieces, tree height and No. of branches, with the values of $b_i \times s_i$ as 3.029, 1.554, 0.313, 0.238, 0.166 and 0.077, respectively. The technical labour productivity in the production of firewood with respect to firewood conversion time increased significantly with the increasing tree height, timber volume/tree and firewood volume/tree, while it showed a decreasing trend with the increasing number of branches/tree, No. of timber pieces/tree, average timber piece volume and tree volume as shown by the positive and negative values of regression coefficients, respectively.

Tree Species

The results of regression analysis between different independent variables of tree parameters and different dependent variables of technical labour productivity (TLP) with respect to total work time and effective work time/tree, timber and firewood production with respect to cross-cutting and firewood conversion time, respectively and according to tree species (mulberry and shisham) are given in the Fig. 33 and tables 40 and 41.

Fig.33: Regression Analysis (Level-I)

TLP T. Work Time —
 TLP Effec. Time —
 TLP Timber —
 TLP Firewood —

= f (DBH, Height, Branches, No. of timber pieces, Timber vol.,
 Av. Piece vol. Firewood vol., Tree vol.)

Species	Regression No.	Regression Equations	P ²	F-value
mulberry	I. 1.1	TLP T. Work Time = $0.190 + 0.105 \times \text{Timber vol.}$	0.043	6.80 *
	I. 1.2	TLP Effec. Time = $0.219 - 0.012 \times \text{Branches}$	0.069	5.60 *
	I. 1.3	TLP Timber = $0.341 + 11.983 \times \text{Av. Piece vol.}$ - $0.802 \times \text{Tree vol.}$	0.137	11.92 ***
	I. 1.4	TLP Firewood = $0.726 - 0.044 \times \text{Branches} - 0.086$ $\times \text{No. of pieces} + 5.465 \times \text{Timber vol.}$ - $3.523 \times \text{Av. Piece vol.}$ + $5.321 \times \text{Firewood vol.} - 4.674 \times \text{Tree vol.}$	0.631	41.59 ***
shisham	I. 2.1	TLP T. Work Time = $0.176 + 0.011 \times \text{Height}$	0.159	8.73 ***
	I. 2.2	TLP Effec. Time = $0.194 + 0.020 \times \text{Height}$	0.238	13.72 ***
	I. 2.3	TLP Timber = $0.813 - 0.459 \times \text{Tree vol.}$	0.489	20.54 ***
	I. 2.4	TLP Firewood = $0.300 + 0.072 \times \text{Height} - 0.189 \times$ $\text{No. of Timber pieces} - 3.173 \times$ $\text{Av. Piece vol.} + 0.292 \times \text{Tree vol.}$	0.544	12.23 ***

Table 40: Influence of different tree parameters on the different dependent variables of technical labour productivity in the felling and conversion of mulberry trees with conventional tools (Level-I.

Regr. No. 1	Dependent variables 2	Independent variables 3	b_i 4	s_i 5	$b_i \times s_i$ 6	R^2 7	F-value 8
I. 1.1	TLP Total Work Time	Timber vol.	0.105	± 0.18	0.019	0.043	6.80 *
I. 1.2	TLP Effective Time	Branches	-0.012	± 1.87	0.022	0.069	5.60 *
I. 1.3	TLP Timber	Av. Timber piece Vol.	11.983	± 0.03	0.359	0.137	11.92 ***
		Tree vol.	-0.802	± 0.26	0.209		
I. 1.4	TLP Firewood	Branches	0.044	± 1.87	0.082	0.631	41.59 ***
		No. of Timb.pieces	-0.086	± 1.95	0.168		
		Timber vol.	5.465	± 0.18	0.984		
		Av. Timber Piece vol.	-3.523	± 0.03	0.106		
		Firewood v.	5.321	± 0.11	0.585		
		Tree vol.	-4.674	± 0.26	1.215		

* significant at 95 % level

** significant at 98 % level

*** significant at 99 % level.

Table 41: Influence of different tree parameters on the different dependent variables of technical labour productivity in the felling and conversion of shisham trees with conventional tools (Level-I).

Regr. No.	Dependent variables	Independent variables	b_i	s_i	$b_i \times s_i$	R^2	F-value
I. 2.1	TLP Total Work Time	Height	0.011	± 4.70	0.052	0.159	*** 8.75
I. 2.2	TLP Effective Time	Height	0.020	± 4.70	0.094	0.238	*** 13.72
I. 2.3	TLP Timber	Tree vol.	-0.459	± 1.54	0.707	0.489	*** 20.54
I. 2.4	TLP Firewood	Height	0.072	± 4.70	0.338		*** 12.23
		No. of timber pieces	-0.189	± 2.32	0.438	0.544	
		Av. Piece vol.	-3.174	± 0.19	0.604		
		Tree vol.	0.292	± 1.54	0.450		

* significant at 95 % level

** significant at 98 % level

*** significant at 99 % level.

Fig.34: Regression Analysis (Level - II)

TLP T. Work Time
 TLP Effect. Time
 TLP Timber
 TLP Firewood

_____ = f (DBH, Height, No. of Branches, No. of Timber
 pieces, Timber vol., Av. Timber piece vol.
 Firewood vol., Tree vol.)

Regression No.	Regression Equations	R ²	F-value
II. 1	TLP T.W.T. = 0.145 + 0.013 x Height	0.229	44.92 ***
II. 2	TLP E.T. = 0.245 + 0.016 x Height	0.180	33.10 ***
II. 3	TLP Timber = 0.266 + 0.067 x Height	0.119	20.30 ***
II. 4	TLP F. Wood = 0.502 + 0.015 x Height - 0.070 x No. of Timber pieces	0.085	6.97 ***

5.2.4.2 Improved Tools (Level-II)

As shown by Fig. 34 and table 42, different technical labour productivity variables (mulberry + shisham) for work with improved tools (Level-II) mostly remained under a highly significant influence of tree height only, as depicted by very high "F" values. Correlation between different technical labour productivity variables and tree height remained very weak with the values of R^2 always less than 0.23.

Technical labour productivity with respect to total work time and effective time and in timber and firewood production with respect to cross-cutting and firewood conversion time showed a very high significant increase with the increasing tree height. In the technical labour productivity in firewood production, No. of timber pieces/tree also appeared as an influencing factor stronger than tree height. The effect of No. of timber pieces/tree on the technical labour productivity in the production of firewood was negative. Which means that technical labour productivity in firewood conversion significantly decreased with the increasing number of timber pieces/tree.

The contents of table 39 and 42 revealed that all technical labour productivity variables for work with conventional tools (Level-I) remained under the strong influence of different tree parameters. But improved tools (Level-II) gave the work performance almost independent of other tree parameters except tree height.

Table 42: Influence of different tree parameters on the different dependent variables of technical labour productivity for work with improved tools (Level-II) in mulberry and shisham.

Regr. No. 1	Dependent variables 2	Independent variables 3	b_i 4	s_i 5	$b_i \times s_i$ 6	R^2 7	F-value 8
II. 1	TLP Total Work Time	Height	0.013	± 5.37	0.070	0.229	*** 44.92
II. 2	TLP Effective Time	Height	0.016	± 5.37	0.086	0.180	*** 33.10
II. 3	TLP Timber	Height	0.067	± 5.37	0.360	0.119	*** 20.30
II. 4	TLP Firewood	Height	0.015	± 5.37	0.081	0.085	***
		No. of timber pieces	-0.070	± 2.02	0.141		6.97

* significant at 95 % level

** significant at 98 % level

*** significant at 99 % level.

Fig.35: Regression Analysis (Level-II)

TLP T. Work Time	
TLP Effec. Time	
TLP Timber	
TLP Firewood	

= f (DBH, Height, Branches, No. of timber pieces, Timber vol., Av. Piece vol., Firewood vol., Tree vol.)

Species	Regression No.	Regression Equations	R ²	F.-value
mulberry	II. 1.1	TLP T. Work Time = 0.110 + 0.016 x Height	0.139	11.42 ***
	II. 1.2	TLP Effec. Time = 0.183 + 0.021 x Height	0.104	8.22 ***
	II. 1.3	TLP Timber = 0.587 + 0.188 x No. of timber	0.110	8.73 ***
	II. 1.4	TLP Firewood = 0.296 + 0.579 x Firewood vol.	0.062	4.70 *
shisham	II. 2.1	TLP T. Work Time = 0.290 + 0.350 x Av. Timber piece vol.	0.234	23.84 ***
	II. 2.2	TLP Effec. Time = 0.470 - 0.027 x Branches + 0.742 x Av. Timber piece vol.	0.275	14.62 ***
	II. 2.3	TLP Timber = - 0.133 + 0.084 x Height	0.162	15.11 ***
	II. 2.4	TLP Firewood = 0.769 - 0.062 x No. of timber pieces	0.261	27.51 ***

Tree Species

The results of regression analysis between different independent variables of tree parameter such as DBH, tree height, No. of branches, No. of timber pieces, timber vol., average timber piece vol., firewood vol. and volume/tree (timber + firewood) and different dependent variables of technical labour productivity (TLP) with respect to total work time and effective work time, timber and firewood production with respect to cross-cutting and firewood conversion time, respectively and according to tree species (mulberry and shisham) are given in the Fig. 35 and tables 43 and 44.

Table 43: Influence of different tree parameters on the different dependent variables of technical labour productivity (TLP) in the felling and conversion of mulberry trees with improved tools (Level-II).

Regr. No. 1	Dependent variables 2	Independent variables 3	b_i 4	s_i 5	$b_i \times s_i$ 6	R^2 7	F-value 8
II.1.1	TLP Total Work Time	Height	0.016	± 3.21	0.051	0.139	11.42 ***
II.1.2	TLP Effective Time	Height	0.021	± 3.21	0.067	0.104	8.22 ***
II.1.3	TLP Timber	No. of Timber pieces	0.188	± 1.60	0.301	0.110	8.73 ***
II.1.4	TLP Firewood	Firewood volume	0.579	± 0.18	0.104	0.062	4.70 *

* significant at 95 % level

** significant at 98 % level

*** significant at 99 % level.

Table 44: Influence of different tree parameters on the different dependent variables of technical labour productivity (TLP) in the felling and conversion of shisham trees with improved tools (Level-II).

Regr. No.	Dependent variables	Independent variables	b_i	s_i	$b_i \times s_i$	R^2	F-value
1	2	3	4	5	6	7	8
II.2.1	TLP Total Work Time	Av. Timber piece Vol.	0.350	± 0.19	0.067	0.234	*** 23.84
II.2.2	TLP Effec. Time	Branches	-0.027	± 2.66	0.072	0.275	***
		Av. Timber piece vol.	0.742	± 0.19	0.141		14.62
II.2.	TLP Timber	Height	0.084	± 5.54	0.465	0.162	*** 15.11
II.2.4	TLP Firewood	No. of timber pieces	0.062	± 2.31	0.143	0.261	*** 27.51

* significant at 95 % level

** significant at 98 % level

*** significant at 99 % level.

5.2.5 Technical Labour Productivity under Maximum Work Stress

A small scale experiment covering two days was carried out to see the performance of conventional and improved tools under an equal and maximum work stress (for details, see subchapter 4.5.1). On each day the workers felled and converted six trees (3 mulberry + 3 shisham) with conventional and improved tools respectively, with a work party size of same 3 workers. The average DBH of trees harvested with conventional and improved tools was 31 and 30 cm respectively.

Time studies, measurement of heart rate during work and work results was also carried out.

The average total pulse for both types of tools remained 111, which means that the workers worked under equal stress in both the work methods.

The results on average technical labour productivity for different productivity variables are given in the table 45.

As shown by the table 45 improved tools at maximum work stress caused a technical labour productivity increase of 32, 33, 112 and 31 % in the productivity variables of total volume with respect to total work time and effective time, timber production with respect to cross-cutting time and firewood production with respect to firewood conversion time respectively, as compared to conventional tools. Results of the paired "t" showed that only the technical labour productivity increase of 112 % in the production of timber with respect to cross-cutting time with improved tools remained significant at 98 % probability level. The reason for the insignificant labour productivity increase of more than 30 % for other productivity variables might be because of only 6 observations in each data set.

Table 45: Technical labour productivity with conventional tools and improved tools in felling and conversion of mulberry and shisham trees at maximum work stress and with a work party size of 3 persons.

Productivity variables	Conventional Tools	Improved Tools	Percentage Increase for Improved Tools
	TLP = (m ³ /man hour)		
Total volume/ Total Work Time	0.486	0.639	+ 32
Total volume/ Effective Time	0.685	0.912	+ 33
Timber volume/ Cross-cutting Time	1.385	2.941	** + 112
Firewood volume/ Firewood conversion time	0.514	0.671	+ 31

* significant at 95 % level

** significant at 98 % level

** significant at 99 % level

Table 46 gives the comparison of percentage increase in technical labour productivity for work with improved tools at normal and maximum work stress with work party size of 3 persons.

Table 46: Technical labour productivity increase with improved tools at normal and maximum work stress

	Normal Work Stress	Maximum Work Stress
Productivity Variables	Percentage Increase in TLP with improved tools	
Total volume/ Total Work Time	48	32
Total volume/ Effective Time	48	33
Timber volume/ Cross-cutting Time	58	112
Firewood volume/ Firewood conversion Time	11	31

Table 46 shows that the improved tools at normal work stress brought about a technical labour productivity increase of 48 % for both the productivity variables of total volume with respect to total work time and effective time in comparison to conventional tools. While this change at maximum work stress remained as 32 and 33 %, respectively. For the other productivity variables like timber volume with respect to cross-cutting time and firewood production with respect to firewood conversion time, the improved tools at maximum stress showed a technical labour productivity increase of 112 and 31 % respectively, against 58 and 11 % increase at normal stress.

Improved tools at normal work stress gave a comparatively better performance in the production of total volume with respect to total work time and effective time, because at maximum work stress conventional tools showed a sharper increase in these productivity variables than improved tools.

At maximum work stress the increase in technical labour productivity with improved tools for the productivity variables of timber production with respect to cross-cutting time and firewood production with respect to firewood conversion time remained approximately 2 and 3 times higher respectively, in comparison to conventional tools.

5.3 HEART RATE

5.3.1 Study Levels and Heart Rate

The data on different heart rate parameters of the workers during felling and conversion of mulberry and shisham trees with conventional (Level-I) and improved tools (Level-II) is given in table 47. The data in this table shows that the average resting heart rate of workers both during Level-I and -II studies remained as 83 pulse beats/min, while other heart rate parameters of average total and working pulse had different values. All the heart rate values remained lower from 5 to 11 pulse beats/min for work with improved tools as compared to work with conventional tools, (Fig. 36 and 37).

Improved tools caused a highly significant decrease of 9, 11, 9 and 11 pulse beats/min in the heart rate parameters of average total pulse, average total pulse effective time, average working pulse and average working pulse effective time respectively, in comparison to work with conventional tools. While the other heart rate parameters like average maximum total pulse and average maximum total pulse effective time, average maximum working pulse and average maximum working pulse effective time showed an insignificant decrease of 5, 9, 8 and 9 pulse beats/min respectively, for work with improved tools. The cause of this insignificant change in the maximum heart values is the limited number of observations.

These results showed that the improved tools not only gave a better work performance but also caused a highly significant to insignificant decrease in physical workload on the workers as depicted by a reduction in different heart rate parameters.

Table 47: Average total and working pulse of workers during felling and conversion of mulberry and shisham trees with conventional (Level-I) and improved tools (Level-II).

Heart Rate Parameters		Study Levels		Change for Level-II
		I	II	
Average Resting Heart Rate		83	83	0
TOTAL PULSE	Average	110	101	-9 ***
	Average Effective Time	116	105	-11 ***
	Average Maximum	136	131	-5
	Average Maximum Effective Time	143	134	-9
WORKING PULSE	Average	27	18	-9 ***
	Average Effective Time	33	22	-11 ***
	Average Maximum	54	46	-8
	Average Maximum Effective Time	59	50	-9

* Significant at 95 % Level
 ** Significant at 98 % Level
 *** Significant at 99 % Level

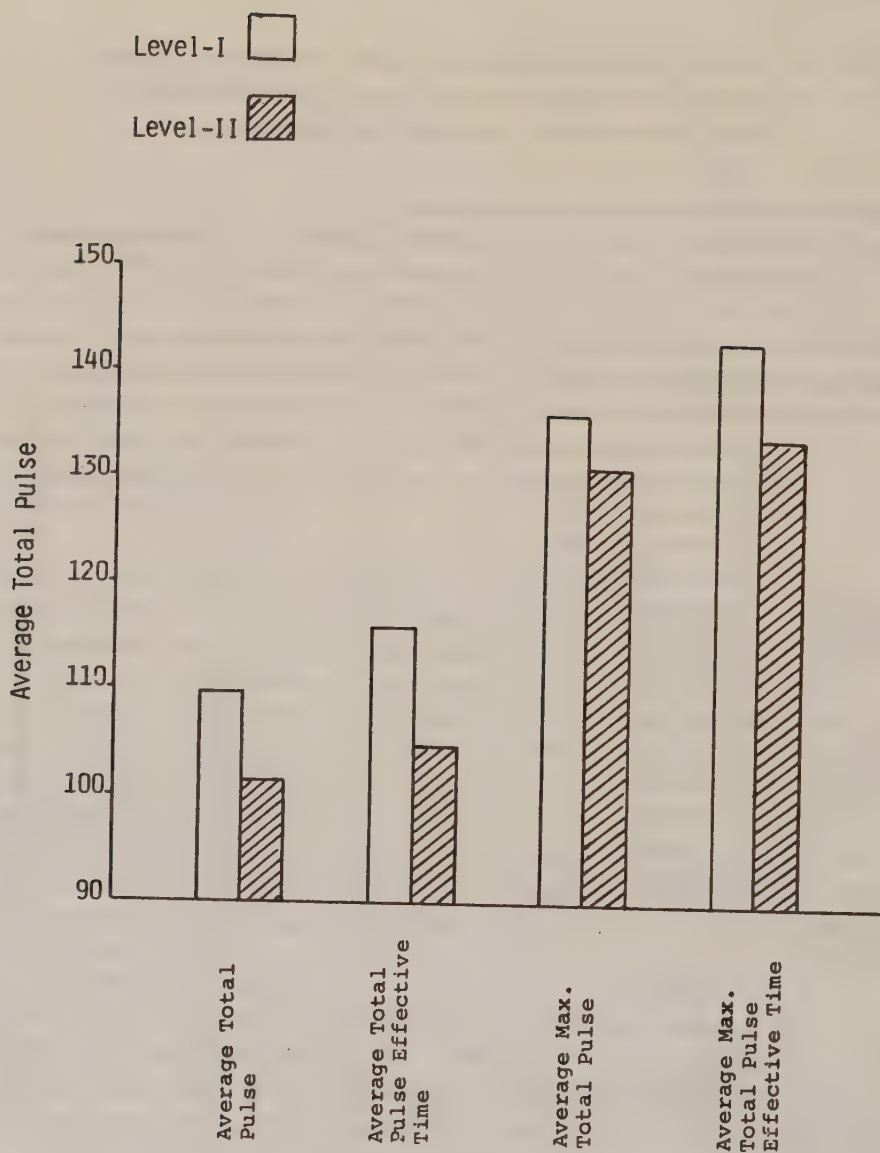


Fig.36: Average total pulse of workers in tree felling and conversion with conventional tools (Level-I) and improved tools (Level-II)

Level-I



Level-II

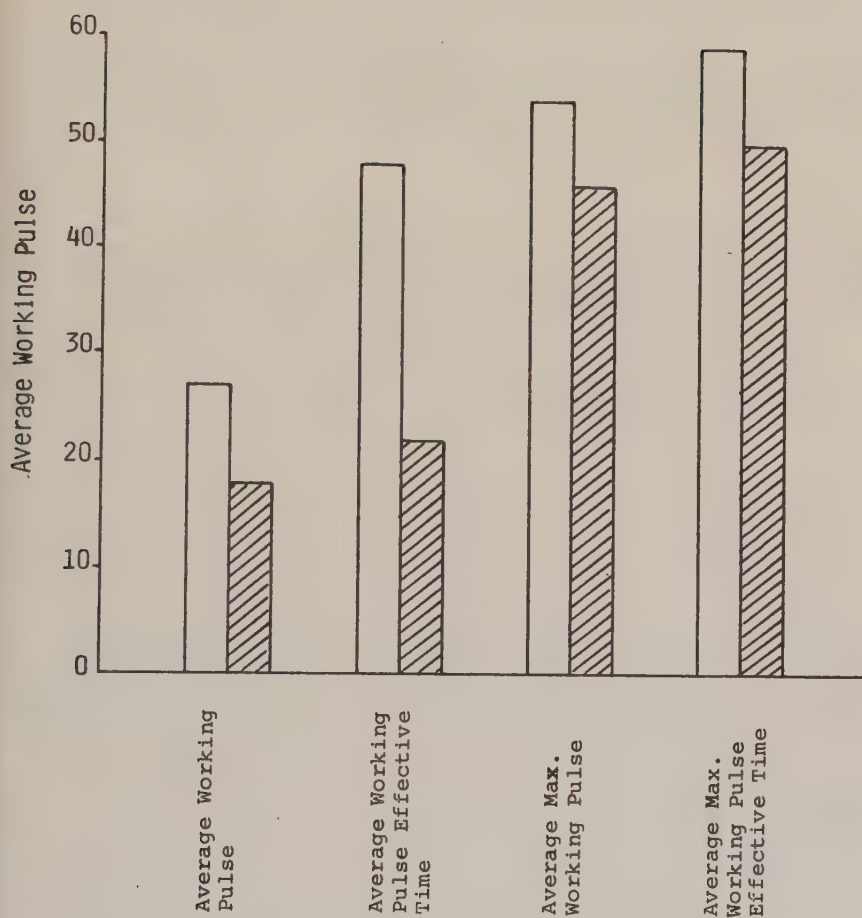


Fig.37: Average working pulse of workers in tree felling and conversion with conventional tools (Level-I) and improved tools (Level-II)

Total Pulse

The average total pulse of the workers remained 110 and 101 pulse beats/min for work with conventional and improved tools respectively. The improved tools caused a highly significant decrease of 9 pulse beats/min in the average total pulse of workers. With conventional tools the workers worked exactly on the limit of sustained performance as 110 pulse beats/min (LOON, 1984), while improved tools caused a significant reduction in the physical workload on the workers.

HILF et al. (1961) compared the performance of workers in one man work party size in tree harvesting work selected from West Germany, Austria and Sweden. The results of this study reported an average working pulse as 118 beats/min, ranging between 97 - 135 for the individual workers. Though the workers in their study worked with improved hand tools and the heart rate likewise was measured manually, even then the average total pulse remained by about 8 and 17 pulse beats higher than the reported figures for conventional and improved tools in this study, respectively.

This difference can be due to the following reasons:

- Personal differences: Heart rate varies from person to person and also depends upon the speed of work. Personal differences are depicted by a higher average resting heart rate of European workers as 86 against an average heart rate value of 83 in this study. Speed of the work is seen in the form of higher work performance of 0.83 m³/man hour for European workers against 0.25 m³/man hour in this study.
- In this study the average total pulse is based on the overall average of four workers working in the work party sizes of 2, 3 and 4 persons. The time study results (chapter 5.1.3) showed that the average delay time increased from 19 to 45 % for conventional tools and from 20 to 29 % for improved tools with the

increasing work party size. Higher delay times means more rest opportunities for the workers and lower physical workload depicted by a lower total pulse. But in the study report by HILF, only one man work party size was used, therefore each worker worked at an higher work stress because of reduced delay time.

TOMANIC and MAJACIC (1983) measured with the help of pulse meter an average total pulse of 119 beats/min during felling and primary conversion of trees with power chainsaw in Yugoslavia.

The average total pulse of the workers for effective time remained as 116 and 105 pulse beats/min for work with conventional and improved tools respectively. Improved tools caused a highly significant decrease of 11 pulse beats in comparison to work with conventional tools. Within the study levels the average total pulse effective time remained by 6 and 4 pulse beats higher than the average total pulse for work with conventional and improved tools, respectively.

An average total pulse effective time of 125 during felling and primary conversion of trees is reported in the studies carried out in Yugoslavia (TOMANIC and MAJACIC, 1983). This figure is by 9 and 20 pulse beats higher than the average total pulse effective time for work with conventional and improved tools, respectively. The reason for higher average total pulse effective time in yugoslavian studies is the different method of heart rate monitoring and power chainsaw work with one man work party size.

The purpose of considering maximum total pulse in this discussion is to see the effectiveness of improved tools in cutting down the peaks of workload.

The average maximum total pulse remained 136 and 131 for work with conventional and improved tools, respectively. Improved tools caused an insignificant reduction of 5 pulse beats.

Within the study levels the average maximum total pulse remained higher by 26 and 30 beats than the average total pulse for work with conventional and improved tools, respectively.

The average maximum total pulse effective time of the workers remained 143 and 134 beats/min for work with conventional and improved tools, respectively. Improved tools caused an insignificant reduction of 9 pulse beats. Within the study levels the average maximum total pulse effective time remained higher by 33 beats/min than the average total pulse for work both with conventional and improved tools.

The cause of insignificant decrease in maximum heart rate values with improved tools is the limited number of observations (only 10 for each work party size). Moreover, the maximum heart values were attained during work with axe, which remained unavoidable even in case of improved tools, where it was used in opening of undercut and in certain case for cutting of branches and releasing of saw binds.

CHRISTENSEN (1964) characterized the work as moderately heavy when the average total pulse varies between 100 - 125 beats/min. Using this criterion the work as a whole remained moderately heavy based upon the values of average total pulse and average total pulse effective time for both types of tools. The maximum pulse values showed that in certain work operations the heart rate crossed the limits of moderately heavy work and became heavy.

Working Pulse

Working pulse of the workers was calculated by taking the difference of total pulse and resting heart rate. Working pulse is a useful indicator of physical workload and also fixes the limits of pulse for sustained performance. As the resting heart rate (pulse) in this study was measured in chair sitting position therefore, the criterion of GRANDJEAN (1981) is used for fixing

the limits of sustained performance. He says that the average working pulse should not exceed 35 pulse beats/min in sustained work.

The main results concerning the working pulse are summarized in table 48.

Table 48: Different heart rate parameters of working pulse during felling and conversion of mulberry and shisham trees with conventional (Level-I) and improved tools (Level-II).

Heart Rate Parameters		Study Levels		Change for Level-II
		I	II	
WORKING PULSE	Average	27	18	*** - 9
	Average Effective Time	33	22	*** - 11
	Average Maximum	54	46	- 8
	Average Maximum Effective Time	59	50	- 9

* significant at 95 % level

** significant at 98 % level

*** significant at 99 % level

The average working pulse remained 27 and 18 pulse beats for conventional and improved tools, respectively. Improved tools caused a highly significant decrease of 9 pulse beats/min in the average working pulse of the workers. Using the criterion of GRANDJEAN (1981) which fixes 35 work pulses as a limit of sustained performance, the workers in this study at the average worked at a lower physical level with 27 work pulses/min for conventional tools and at a much lower physical level with 18 work pulses/min for improved tools. Accordingly the improved tools caused a highly significant reduction in the physical workload on the workers.

HILF et al. (1961) reported an average working pulse of 33 beats/min, which is 6 and 15 beats/min higher than for the work with conventional and improved tools in this study, respectively. The reasons for this difference have already been discussed.

The average working pulse effective time remained as 33 and 22 pulse beats/min for work with conventional and improved tools respectively. Improved tools caused a highly significant decrease of 11 pulse beats/min. Using the criterion of GRANDJEAN (1981), the workers worked almost near to the limit of sustained performance with conventional tools and 13 work pulse/min less than the limit of sustained performance with improved tools. The workers worked with improved tools at a highly significantly low physical level as depicted by the difference in the working pulse.

HILF et al. (1961) reported an average working pulse effective time of 37 pulse beats/min, which is 4 and 15 pulse beats/min higher than for work with conventional and improved tools in this study, respectively.

The average maximum working pulse remained as 54 and 46 pulse beats/min for work with conventional and improved tools, respectively. Improved tools caused an insignificant decrease of 8 pulse beats/min. Within the study levels the average maximum working pulse remained by 27 and 28 pulse beats/min higher than

the average working pulse for work with conventional and improved tools, respectively.

The average maximum working pulse of the workers for effective time remained 59 and 50 pulse beats/min for work with conventional and improved tools, respectively. Improved tools caused an insignificant reduction of 9 pulse beats/min of the workers in comparison to work with conventional tools. Within the study levels the average maximum working pulse effective time remained 32 pulse beats/min higher than the average working pulse both for conventional and improved tools.

The working pulse both average maximum and average maximum effective time remained fairly high above the limit of continuous performance (criterion of GRANDJEAND, 1981) both for work with conventional and improved tools.

For work with conventional tools the use of axe remained dominant and the works like felling, debranching and firwood conversion were purely performed with axe. As the axe work is very strenuous therefore, all the heart rate values for work with conventional tools remained higher in comparison to improved tools. Whereas the axe work in Level-II studies also remained unavoidable under certain situations.

The causes of insignificant decrease in the maximum working pulse values with improved tools have already been discussed.

5.3.2 Work Elements and Heart Rate

Average Total Pulse

The data on the average total pulse of the workers according to different work elements for work with conventional (Level-I) and improved tools (Level-II) is given in the table 49. As shown by this table and Fig. 38 the improved tools caused a reduction in the average total pulse of the workers upto a maximum of 24 pulse beats/min for almost all the work elements except operational delay, where it remained equal for both types of tools and measuring, where it increased by 4 pulse beats/min for work with improved tools. The reduction in the average total pulse for work with improved tools remained significant for the work elements of preparation and personal delay, while it remained highly significant for the work elements of felling, hang-up, firewood conversion and cross-cutting.

Delay Time Work Elements

Preparation: In the work of preparation the average total pulse of the workers remained 98 and 92 pulse beats/min for work with conventional and improved tools, respectively. Improved tools caused a significant decrease of 6 pulse beats/min as compared to work with conventional tools.

Table 49: Average total pulse of the workers according to different work elements in felling and conversion of mulberry and shisham trees with conventional (Level-I) and improved tools (Level-II).

Work Time	Work Elements	Level-I	Level-II	Change for Level-II
		Average Total Pulse		
Delay Time	Preparation	98	92	- 6 *
	Operational Delay	94	94	0
	Personal Delay	93	91	- 2 *
Average Total Pulse Delay Time		93	91	- 2 *
Effective Time	Walk	97	96	- 1
	Felling	132	108	- 24 ***
	Hang-up	122	99	- 23 ***
	Debranching	116	112	- 4
	Firewood Conversion	111	106	- 5 ***
	Measuring	98	102	+ 4
	Cross-cutting	113	107	- 6 ***
Average Total Pulse Effective Time		116	105	- 11 ***

* significant at 95 % level
 ** significant at 98 % level
 *** significant at 99 % level

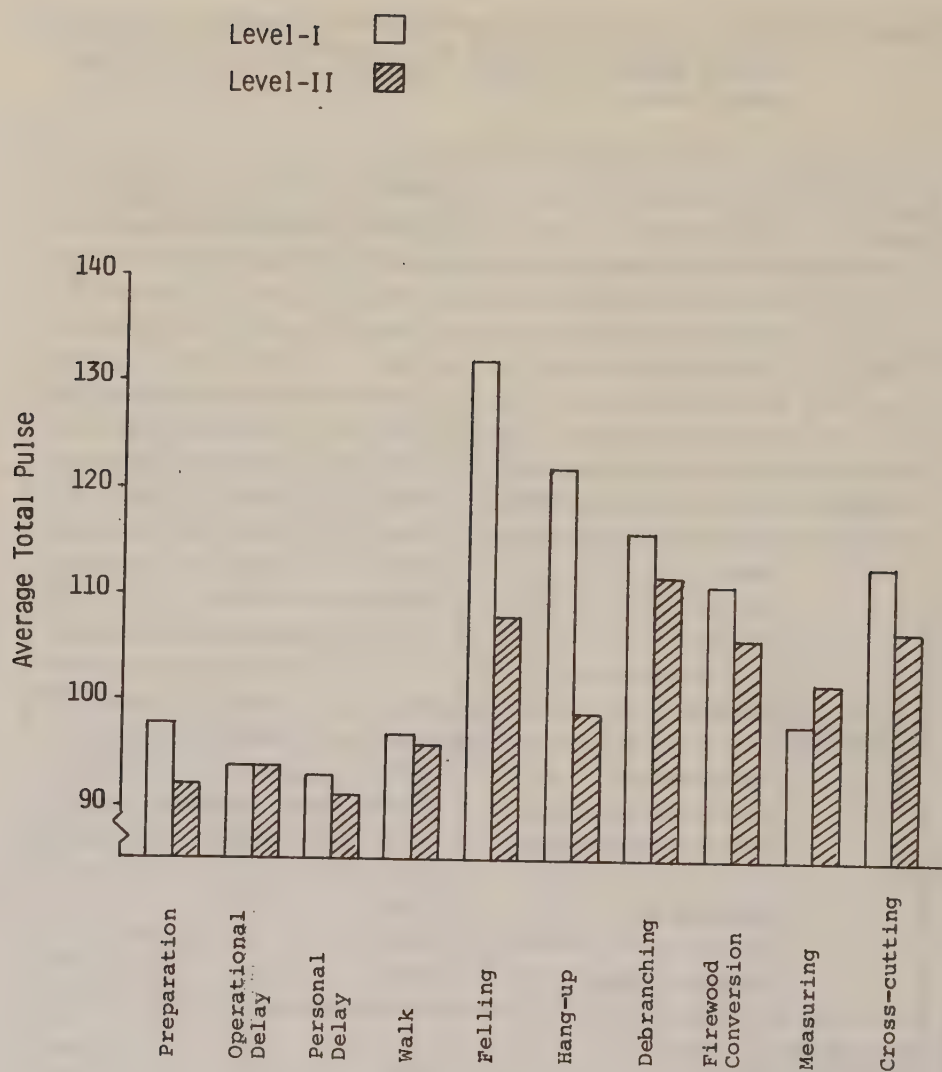


Fig.38: Average total pulse of the workers in tree felling and conversion with conventional tools (Level-I) and improved tools (Level-II)

The reason for the significant decrease in heart rate for preparation with improved tools is an increase of more than 100 % in the preparation time with improved tools as compared to conventional tools. The work of preparation of hand tools is not a heavy job and there seems to be no reason for the difference of physical workload in preparation for work with these tools. The length of preparation time at the start of work is of no importance for the difference of heart reate, but at the end of work longer preparation time means good recovery of workers from the stress experienced during the last work operation performed.

TOMANIC and MAJACIC (1983) in their studies on the work stress in the primary felling and conversion of trees in Yugoslavia, reported an average total pulse of 109 in the work of preparation. This figure is 11 and 17 pulse beats/min higher than the average total pulse for preparation with conventional and improved tools, respectively. The reasons for this difference have already been discussed in chapter 5.3.1.

Operational Delay: The average total pulse in operational delay remained 94 pulse beats/min both for Level-I and Level-II. It means that there is no difference of workload in operational delays for the two types of tools.

Personal Delay: The average total pulse during personal delays remained 93 and 91 pulse beats/min for conventional and improved tools, respectively. The improved tools caused a significant decrease of 2 pulse beats/min during personal delays in comparison to conventional tools. In personal delays there is no effective work therefore, the tools directly cannot be accounted for this difference. The reasons for lower total pulse during personal delays is discussed under average total pulse delay time in the following paragraph.

Average total pulse delay time: The work delays occured almost independent of tools. In delay times there was no real work of

tree felling and conversion. Therefore the difference in the heart rate of workers during delays in Level-I and II studies cannot directly be accounted to the types of tools. But lower heart rate during delays reflected the level of stress experienced by the workers during effective work. The average total pulse delay time remained 93 and 91 pulse beats/min for work with conventional and improved tools, respectively. Improved tools caused a significant decrease of 2 pulse beats/min in comparison to conventional tools. It means that during the effective work with improved tools, the workers experienced less physical stress as depicted by a quick and good recovery of workers during delays, even though the delay time was by about 14 % less for work with improved tools.

TOMANIC and MAJACIC (1983) reported a delay time average total pulse of 110 beats/min. This is 17 and 19 pulse beats/min higher than for work with conventional and improved tools, respectively. The reason for this difference is the chain saw work and one man work party size.

Effective Time Work Elements

Walk: The walk or searching of next tree is independent of tools and tree parameters. But in this study it has been grouped with the effective time work elements, because the improved tools in comparison to conventional tools were more in number and therefore, had more weight which could account for the difference of workload in their carrying from one place to the other.

The average total pulse in walk remained 97 and 96 pulse beats/min in carrying of conventional and improved tools respectively. This difference is insignificant. The conventional tools were less in number and weight and should have produced less physical workload on the worker during their transportation in the stand. But in contrast to it the average total pulse while walking with conventional tools remained high probably because of insensibility

of heart rate to the suddenly changing workloads and projection of high physical workload experienced in effective work with conventional tools.

Felling: In felling the average total pulse of the workers remained 132 and 108 pulse beats/min for work with conventional and improved tools, respectively. Improved tools caused a highly significant decrease of 24 pulse beats/min in comparison to work with conventional tools. Felling with conventional tools comprised of pure axe work and using the criterion of CHRISTENSEN (1964) was a heavy work. While the work of felling with improved tools remained moderately heavy. In felling with conventional tools the workers worked well above the limit of sustained performance (LOON, 1984). While with improved tools felling work remained below this limit. Felling work with conventional tools was the heaviest job in comparison to all other work elements in a work cycle of tree felling and conversion.

HANSSON et al. (1966) in their studies on tools and ergonomics in Indian Logging Operations, reported an average total pulse of 126 beats in felling of trees. This figure is by 6 pulse beats/min less than the average total pulse in felling with conventional tools and 18 pulse beats/min higher than average total pulse in felling with improved tools. Difference can be due to the workers and tree species.

Hang-up: Average total pulse in releasing the hung-up trees remained 122 and 99 pulse beats in Level-I and Level-II studies. The difference was not because of the kinds of tools, but due to the training of workers in proper work methods during Level-II studies. In Level-I studies the workers had no concept of directional felling therefore, the hang-up of trees was quite frequent. The releasing of hang-up is a very heavy job and the heart rate correspondingly went high. But in case of Level-II studies the workers always practiced directional felling to avoid hang-ups and were always successful. Whatsoever hang-up occurred during

Level-II studies was of a minor nature and was released without much effort. Therefore the work of releasing hang-up in Level-II studies remained light and caused a highly significant decrease of 23 pulse beats/min in comparison to Level-I studies.

Debranching: The average total pulse in the work of debranching remained 116 and 112 pulse beats/min for work with conventional and improved tools, respectively. The decrease of 4 pulse beats/min is insignificant. The work of debranching remained moderately heavy with both types of tools. Although debranching in Level-II studies was mainly done with bowsaw, the use of axe could not be avoided in certain situations. Use of axe and less number of heart rate observation are the main reasons for insignificant reduction in the average total pulse in debranching with improved tools. Using the criterion of LOON (1984), the workers with both types of tools worked above the limit of sustained performance in debranching of trees.

HANSSON et al. (1966) reported an average working pulse of 111 beats/min (measured manually) in the work of lopping the trees with axe. This figure is nearly equal to the total pulse in debranching of trees with improved tools and 5 pulse beats lower than for conventional tools in this study.

In the study of TOMANIC and MAJACIC (1983), conducted in Yugoslavia, an average heart rate of 133 pulse beats/min has been reported in debranching work with axe. This figure is 17 and 21 pulse beats/min higher than the values of average total pulse in debranching with conventional and improved tools, respectively. The reasons for these differences can be the workers, tree species and work party size.

Firewood conversion: The average total pulse of the workers in the work of firewood conversion came up to 111 and 106 pulse beats/min for work with conventional and improved tools, respectively. Improved tools caused a highly significant decrease of

5 pulse beats/min. The work of firewood conversion with both types of tools remained moderately heavy (CHRISTENSEN, 1964). In firewood conversion with conventional tools (axe) the workload exceeded the limit of sustained performance (LOON, 1984), while the average total pulse in firewood conversion with improved tools (bowsaw and bill-hook) was below this limit.

Measuring: In measuring work the average total pulse of the workers amounted to 98 and 102 pulse beats/min in case of conventional and improved tools, respectively. Improved tools caused an insignificant increase of 4 pulse beats/min. No reason can be accounted for this unexpected change.

Cross-cutting: In cross-cutting the average total pulse of the workers remained 113 and 107 pulse beats/min for work with conventional and improved tools, respectively. Improved tools caused a highly significant decrease of 6 pulse beats/min in the average total pulse of the workers as compared to work with conventional tools. The work of cross-cutting with both types of tools was moderately heavy (CHRISTENSEN, 1964) and the workload on the workers in cross-cutting with conventional tools remained above the limit of sustained performance while the heart rate in cross-cutting work with improved tools was 3 pulse beats/min less than this limit.

HANSSON et al. (1966) in India and TOMANIC and MAJACIC (1983) in Yugoslavia studied the heart rate of workers manually and with the help of pulse meter engaged in tree harvesting. These authors measured an average total pulse of 117 pulse beats/min for Indian workers and 130 pulse beats/min for Yugoslavian workers. They differ from one another and also from the results reported in this study as well. Probably reason for this difference is the different locality factors, personal variation, different tools and heart rate study methods.

Average total pulse effective time: The average total pulse of the workers for the effective time work elements for work with conventional (Level-I) and improved tools (Level-II) is already discussed under chapter 5.3.1.

In work with conventional tools the work element of tree felling, followed by hang-up were the most difficult one with a very high physical workload and workers worked well above the limit of sustained performance. Firewood conversion and cross-cutting proved to be equal on the basis of physical workload. Debranching with axe was the heaviest job after felling and releasing of hang-ups. Improved tools showed their maximum effect of cutting down the physical workload in the most difficult operation. Felling of trees was the most difficult work with conventional tools but improved tools made it even lighter than firewood conversion and cross-cutting with conventional tools. Same is the case with releasing of hang-up, which was rendered nearly as easy as measuring.

Average working pulse of the workers with respect to different work elements in felling and conversion of mulberry and shisham trees with conventional and improved tools is given in table 50 and Fig. 39.

Table 50: Average Working Pulse of Workers in Felling and Conversion of mulberry and shisham trees with conventional (Level-I) and improved tools (Level-II)

Work Elements	Level-I	Level-II	Change in Level-II
	Average Working Pulse		
1. Preparation	18	10	- 8 ***
2. Operational Delay	13	6	- 7 **
3. Personal Delay	8	7	- 1
4. Walk	13	14	+ 1
5. Felling	51	25	- 26 ***
6. Hang-up	44	19	- 25 ***
7. Debranching	33	30	- 3
8. Firewood Conversion	30	23	- 7 ***
9. Measuring	17	17	0
10. Cross-cutting	30	24	- 6 ***

* significant at 95 % Level

** significant at 98 % Level

*** significant at 99 % Level

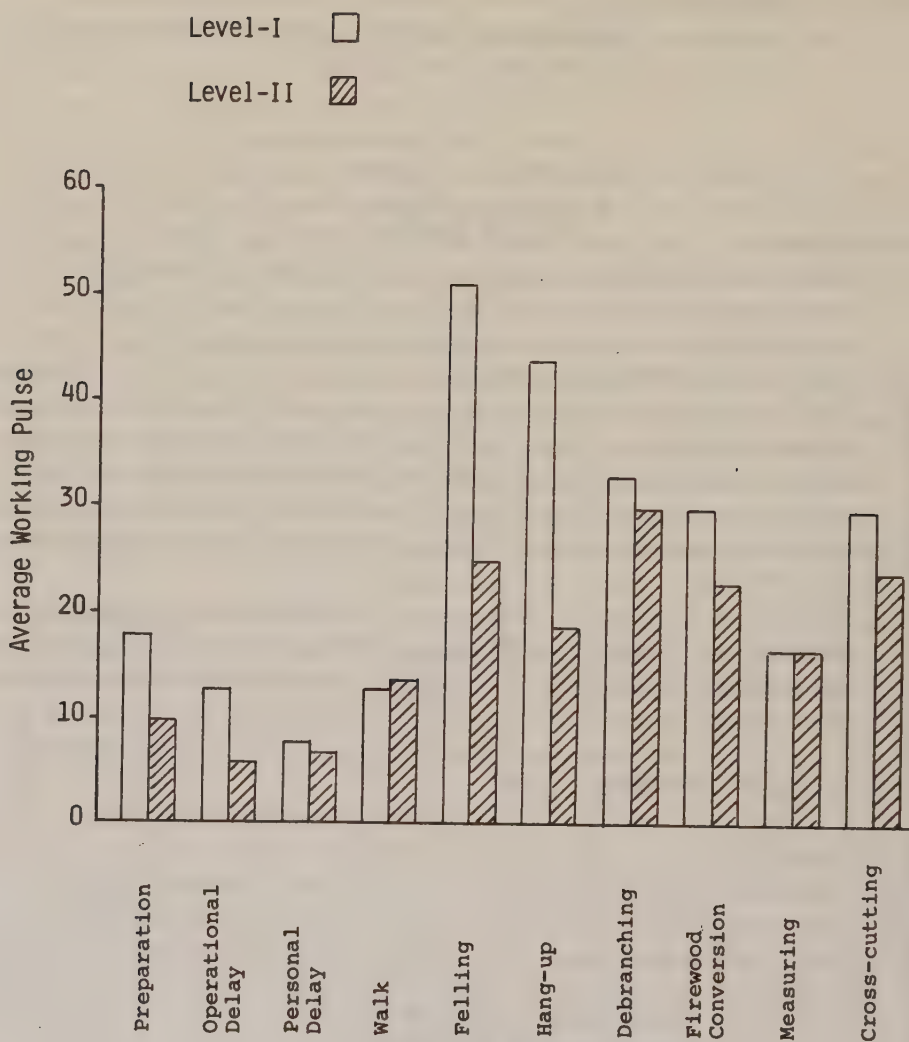


Fig.39: Average working pulse of workers in tree felling and conversion with conventional tools (Level-I) and improved tools (Level-II)

5.3.3 Work Party Sizes and Heart Rate

Total Pulse

Table 51 shows the different heart rate parameters of total pulse of the workers in felling and conversion of trees with conventional (Level-I) and improved tools (Level-II) and in different work party sizes.

Average total pulse: As shown by table 51 the average total pulse of the workers for work with conventional tools remained 113, 106 and 107 for the work party sizes of 2, 3 and 4 persons, respectively. The work party size of 2 persons with conventional tools worked at a higher workload and above the limit of sustained performance (LOON, 1984), while the work party sizes of 3 and 4 persons remained at nearly comparable workload and below the limit of sustained performance. The average total pulse for work with improved tools remained 107 for the work party size of 2 persons and 101 pulse beats/min for the work party sizes of 3 and 4 persons. Use of improved tools caused a highly significant reduction in the average total pulse by 6, 5 and 6 pulse beats/min for the work with the work party sizes of 2, 3 and 4 persons, respectively. Even with improved tools the work party size of 2 persons experienced a higher physical workload than the work party sizes of 3 and 4 persons. The work party size of 2 persons in both the study levels worked at a higher physical workload than the work party sizes of 3 and 4 persons.

Average total pulse effective time: The average total pulse of the workers during effective work for conventional tools (Level-I) remained as 117, 112 and 118 pulse beats/min for the work party sizes of 2, 3 and 4 persons, respectively. Nearly equal and higher workload was experienced by the work party sizes of 2 and 4 persons followed by the work party size of 3 persons. All the work parties worked above the limit of sustained performance with conventional tools. Improved tools (Level-II) caused a highly significant re-

Table 51: Average total pulse of workers in different work party sizes during felling and conversion of trees with conventional.(Level-I) and improved tools (Level-II).

Heart Rate Parameters	Work Party Sizes (persons)	Mean		Change for Level-II
		Level-I	Level-II	
Average Total Pulse	2	113	107	- 6***
	3	106	101	- 5***
	4	107	101	- 6***
Average Total Pulse Effective Time	2	117	110	- 7***
	3	112	105	- 7***
	4	118	106	- 12***
Average Maximum Total Pulse	2	138	129	- 9
	3	134	136	+ 2
	4	133	127	- 6
Average Maximum Total Pulse Effective Time	2	148	130	- 18
	3	141	142	+ 1
	4	139	130	- 9

* significant at 95 % Level
 ** significant at 98 % Level
 *** significant at 99 % Level.

duction in the average total pulse effective time by 7, 7 and 12 pulse beats/min for the work party sizes of 2, 3 and 4 persons, respectively. The highest reduction was for the work party size of 4 persons followed by an equal reduction in case of work party sizes of 2 and 3 persons. The average total pulse effective time for work with improved tools remained as 110, 105 and 106 pulse beats/min for the work party sizes of 2, 3 and 4 persons, respectively. With improved tools highest workload was experienced by the work party size of 2 persons, working exactly at the limit of sustained performance followed by work party size of 4 and 3 persons.

With both types of tools the work party size of 2 persons experienced the maximum workload, while least stress was for the work party size of 3 persons.

Average maximum total pulse: The average maximum total pulse for work with conventional tools remained 138, 134 and 133 pulse beats/min for the work with party sizes of 2, 3 and 4 persons, respectively. Improved tools caused an insignificant decrease of 9 and 6 pulse beats/min for the work party size of 2 and 4 persons, respectively. While it insignificantly increased by 2 pulse beats/min for the work party size of 3 persons.

Average total maximum pulse of the workers for work with improved tools remained as 129, 136 and 127 pulse beats/min for the work party sizes of 2, 3 and 4 persons, respectively. With conventional tools maximum stress was experienced by the work party size of 2 persons, while with improved tools work party size of 3 persons worked at higher workload.

Average maximum total pulse effective time: The average maximum total pulse of the workers during effective work remained as 148, 141, 139 pulse beats/min for the work party sizes of 2, 3 and 4 persons, respectively. Maximum workload was experienced by the work party size of 2 persons, followed by the work party sizes

of 3 and 4 persons. Improved tools caused an insignificant decrease in the maximum total pulse effective time by 18 and 9 pulse beats/min for work party sizes of 2 and 4 persons, respectively, while it showed an insignificant increase of 1 pulse beats/min for the work party size of 3 persons. With improved tools maximum work stress was experienced by the work party size of 3 persons, followed by a comparable workload experienced by the work party sizes of 2 and 4 persons.

The maximum total pulse values are not a valid estimate of sustained workload in comparison to average total pulse values, but indicate only the momentary limits of peak loads.

Different values of maximum total pulse showed that all work party sizes with both types of tools worked well above the limit of sustained performance during periods of maximum stress. But in general improved tools (Level-II) remained effective in cutting down the peak loads.

Table 52 shows the different heart rate parameters of average working pulse of the workers for work with conventional and improved tools and in different work party sizes.

On the basis of total pulse values, (excluding maximum pulse values) the work party size of 2 persons experienced maximum work stress, followed by the work party size of 4 persons. The least workload was experienced by the work party size of 3 persons. If we take the maximum pulse values, again the work party size of 2 persons remained under maximum work stress and work party size of 3 and 4 persons can be regarded as comparable.

Improved tools caused a highly significant decrease in physical workload in comparison to conventional tools as depicted by the lower values of average total pulse.

Table 52: Heart rate parameters of average working pulse in felling and conversion of trees with conventional (Level-I) and improved tools (Level-II) and in different work party sizes.

Heart Rate Parameters	Work Party Sizes (persons)	Mean		Change for Level-II
		Level-I	Level-II	
Average Working Pulse	2	33	17	- 16 ^{***}
	3	27	16	- 11 ^{***}
	4	24	19	- 5 ^{***}
Average Working Pulse Effective Time	2	38	18	- 20 ^{***}
	3	32	18	- 14 ^{***}
	4	32	21	- 11 ^{***}
Average Maximum Working Pulse	2	57	42	- 15
	3	54	57	+ 3
	4	47	39	- 8
Average Maximum Working Pulse Effective Time	2	67	43	- 24
	3	60	63	+ 3
	4	52	44	- 8

Heart Rate and Tree Parameters

The results of a multiple linear regression analysis showed no significant relationship between heart rate parameters of average total pulse (dependent variables) and DBH of the tree (independent variables) for both conventional (Level-I) and improved tools (Level-II).

5.3.4 Individual Workers and Heart Rate

Average Resting Heart Rate

The heart rate of the workers after 10 - 15 minutes rest in the chair sitting position was measured every day before the start of work during the entire period of the study. Average of these values according to the individual workers is given in table 53.

Table 53: Average resting heart rate of different workers.

Worker No.	No. of Observations	Average Resting Heart Rate	Standard Deviation
1	41	78	$\pm$ 5.9
2	31	82	$\pm$ 7.5
3	36	89	$\pm$ 6.5
4	41	83	$\pm$ 5.6

The average resting heart rate of the workers varied between 78 to 89 pulse beats/min. There was a very large day to day variation in the resting heart rate of the workers. The daily resting heart rate fluctuations were highest for worker No. 2 with the highest value of standard deviation as ± 7.5 , followed by worker No. 3, 1 and 4 with the values of standard deviation as ± 6.5 , ± 5.9 and ± 5.6 , respectively.

Smoking and Resting Heart Rate

All the 4 workers were smokers. Near to the end of studies the worker No. 3 left smoking. A marked change in his resting heart rate values measured afterwards was noticed.

Condition	No. of Observations	Average Resting Heart Rate	Change without smoking
With smoking	28	92	- 12
Without smoking	8	80	

The worker had an average resting heart rate of 92 when he was a smoker, but after he left smoking his average resting heart rate came down to 80 beats/min. This means that smoking was responsible for an increase of 12 pulse beats/min in the resting heart rate of this worker.

Average Total Pulse

The data on the average total pulse of the individual workers during the work of tree felling and conversion with conventional (Level-I) and improved tools (Level-II) is given in the table 54.

The average total pulse of the workers varied between 105 and 113 for work with conventional tools and between 96 and 106 for work with improved tools. The average total pulse remained lower by 1 to 9 pulse beats/min for work with improved tools in comparison to conventional tools and this change remained significant to highly significant.

In work with conventional tools, maximum workload was experienced by worker No. 2 with an average total pulse of 113 beats/min. With this average total pulse he worked at higher workload than the limit of sustained performance (LOON, 1984), followed by worker No. 4 who nearly remained on the limit of sustained performance with an average total pulse of 111. Workers No. 3 and 1 remained well below the limit of sustained performance with the average total pulse of 107 and 105 beats/min, respectively.

All of the workers in Level-II studies worked well below the limit of sustained performance. Minimum workload was experienced by the worker No. 1 with an average total pulse of 96 beats/min, while the worker No. 2, 3 and 4 worked comparatively at a higher workload with an average total pulse of 105, 106 and 106 pulse beats/min, respectively.

Table 54: Average Total Pulse of the individual workers during felling and conversion of trees with conventional (Level-I) and improved tool (Level-II)

Worker No.	Average Total Pulse		Change for Level-II
	Level-I	Level-II	
1	105	96	- 9 ***
2	113	105	- 8 ***
3	107	106	- 1 *
4	111	106	- 5 ***

* significant at 95 % Level

** significant at 98 % Level

*** significant at 99 % Level

Improved tools caused a significant decrease of 1 pulse beats/min in the average total pulse of worker No. 3 and highly significant decrease of 9, 8 and 5 pulse beats/min in the average total pulse of worker No. 1, 2 and 4, respectively.

The worker No. 1 remained the fittest with least average total pulse values as 105 and 96 both for work with conventional and improved tools, respectively and this fact exactly corresponds to the visual observations about the physical performance of the workers during work.

HILF et al. (1961) measured the heart rate of workers manually and reported the figures of average total pulse for the individual workers ranging between 97 to 135 pulse beats/min. This large variation of average total pulse among the workers can only be accounted to personal differences.

Table 55 gives the values of average working pulse of the individual workers.

Table 55: Average Working Pulse of the individual workers during felling and conversion of trees with conventional (Level-I) and improved tools (Level-II).

Worker No.	Average Working Pulse		Change for Level-II
	Level-I	Level-II	
1	24	18	- 6 ***
2	28	24	- 4 ***
3	22	14	- 8 ***
4	30	22	- 8 ***

* significant at 95 % level

** significant at 98 % level

*** significant at 99 % level

6 DISCUSSIONS AND CONCLUSIONS

6.1 DISCUSSIONS

The history of managed forestry in Pakistan is more than a century old. Since then the focus of all research activities mostly remained forest management and silviculture and little attention was paid to the improvement of forest operations. Therefore, the methods and tools used in these operations are the same as they were centuries before. Only with the coming up to a few forest roads and public roads, long distance timber transport through the agency of rivers have been substituted by motor transport. These primitive tools and timber harvesting methods have many disadvantages, like high timber wastage, low labour productivity and high physical workload, which ultimately not only result into unnecessary delays in harvesting programmes, but also poor income for the workers as well. For searching out the possibilities of improvement of timber harvesting operations both for the benefit of the work and the worker, activities have been started at the Pakistan Forest Institute, Peshawar, nearly five years ago with the help of Federal Republic of Germany. The present study is a part of research activities under this programme. The result of this study highlight the following facts:

The study in question is the first of its kind in the country for the comparison of working means and methods in the form of work performance and physical workload in timber harvesting. The results of the study showed that the improved tools are not only efficient in giving a highly significant increase in the technical labour productivity, but also caused a highly significant reduction in the physical workload as well. Higher labour productivity at reduced workload is of great significance for the improvement of forest work and provides concrete grounds for the introduction of improved tools and vocational training of forest workers.

This study although is the first of its kind, but not the final one for the improvement of forest work in the country. Rather it has opened up a **new field of research** with the possibilities of series of investigations on ergonomics and labour productivity not only in timber harvesting work, but also in other fields of operational forestry. Moreover, this study remained only concerned to Changa Manga Forest Plantation. But other forest areas of Pakistan provide equally useful opportunities of such investigations, because of difference of personal factors, tree species, work conditions and work requirements.

The results of the study are not the final one even within their own meanings. But indicate a number of research problems for future studies to achieve the perfection.

In this study, the workers worked in definite work cycles and the work on the next tree was started only when the first tree was completely finished. This was important for correlating different work times to different tree parameters. But normally the workers work without such a work sequence, which might influence the work performance. For developing a most reliable figure these results need to be tested against the results of **follow-up studies**. So it is needed that the follow-up observation in timber harvesting may be carried out with the same workers in the same area with both types of tools.

The results of the study have shown that in felling and conversion of mulberry trees, the raker-tooth crosscut-saw and bowsaw gave very high significant increase in technical labour productivity, but for shisham trees performance of these tools remained poor in comparison to conventional axe and peg-tooth crosscut saw. Besides different nature of shisham wood there can be many other reasons, providing the possibilities of studies to eradicate the difficulties in felling and conversion of shisham trees with improved tools.

The results of this study indicate the necessity of the following investigations:

- Studies can be planned for choosing the optimum saw setting parameters of raker-tooth crosscut saw for cutting of mulberry and shisham and many other tree species in the form of maximum crosscutting efficiency as area cut/min.
- It has also been observed that in cutting of heavy shisham the raker-tooth crosscut saw gave serious saw binds. The reasons for this trouble need to be investigated and possible remedies suggested.
- In firewood conversion of mulberry and shisham, improved tools did not give a better performance in comparison to conventional axe in the form of technical labour productivity. The causes of this difficulty need to be explored and possible remedies suggested.
- The raker-tooth crosscut saw and bowsaws were used in this study under the single category of improved tools. But because of different work limitations of these two types of saws a separate study is needed for the testing of raker-tooth crosscut saw and bowsaw in the form of work performance in cutting of different tree diameters.
- In this experiment the workers received a 2 weeks training in the methods of work and tool maintenance. In this period they very quickly picked up the work methods because of their experience in timber harvesting and gave good demonstrations. But during the course of studies it was realized that this much training proved to be insufficient to improve their work habits. For example to carry all the tools with them from one work place to the other. Their failure in doing so remained a common cause of time loss during work with improved tools. In tool maintenance 2 weeks training remained altogether in-

sufficient. So further studies are needed to determine the optimum training period with respect to work habits and maintenance of tools. Such studies can only be undertaken when permanent programmes for the training of labour have already started.

6.2 CONCLUSIONS

From the results of the study the following conclusions can be drawn

Plan of studies for Further Investigations

The study itself, besides giving convincing results on the usefulness of improved tools over conventional tools in the form of higher technical labour productivity and less physical workload, also provides a complete research plan starting from methods, data collection, data analysis and presentation of results as basis for the future investigations on the comparison of working means and methods for choosing the optimum technology, not only in timber harvesting but also in other fields of operational forestry.

Vocational Training of the Forest Workers

The results of this study have shown that only a short training of forest workers covering a period of 2 weeks, although deficient in many respects, but still caused a significant increase in the labour productivity and a reduction in the physical workload. Therefore, it has been concluded that vocational training of forest workers is essential for increased work performance.

Such training programmes are the responsibility of forestry organizations both for the benefit of employer and employee. Properly trained forest workers are benefited in the form of increased work output, less physical workload, higher income and reduced chances of occupational accidents. Training of wor-

kers benefits the employer as well in the form of better quality of work, smooth running of work without interruptions, timely execution and completion of timber harvesting operations and more profit because of reduced timber losses and cut down in the social costs due to decreased rate of occupational accidents and diseases. Therefore, the above facts reveal that the vocational training of forest workers is an urgent need both for the interest of forest departments and the workers.

In the light of these facts, programmes need to be formulated for the training of forest workers for optimum work and of the supervisors for efficient control. Some of the main points which should form the basis of such training programmes are given as under:

Workers:

- Proper work methods and tools
- Maintenance of tools
- Personal safety and ergonomics
- Food and hygiene.

Supervisors:

- Proper work methods and tools
- Safety at work and ergonomics
- significance of tools maintenance
- care and storage of tools
- proper work organization.

Now the question arises that who should give this training and where these facilities should be located. To provide trained personnels to staff the proposed training centres, the technicians of the Pakistan Forest Institute, with the help of a foreign expert should constitute a mobile training party, which should visit different plantations in Panjab and impart short training to the workers and staff of the forest departments (Forest Guards and Block Officers) right at the work place. From these the workers and staff members giving good response

to this training should be selected, trained further as teachers and instructors of the future.

To start with and as one of the places for permanent labour training centres, Changa Manga Forest Plantation offers the ideal opportunities for such activities, because of its location and available residential facilities. Teaching aids in proper work methods, tool maintenance and ergonomics should be prepared by the research staff of the Pakistan Forest Institute.

Introduction of improved tools

The results of this study have shown that the improved tools (raker-tooth crosscut saw and bowsaw), with a very short training of workers, resulted into a highly significant increase in the technical labour productivity in timber harvesting in comparison to conventional tools and methods. Moreover, the improved tools were not only advantageous in giving a higher work performance, but also caused a significant reduction in the physical workload. The cost of work/m³ of production (timber + firewood) also remained lower for improved tools and was calculated as Rs. 21.89 and Rs. 24.22 with improved tools and conventional tools, respectively (Appendix-I). Improved tools remained by about 11 % more economical in felling and conversion of mulberry and shisham trees. With all these advantage, need for the introduction of improved tools in timber harvesting operations is greatly realized.

Procurement of Improved Tools: Raker-tooth crosscut saw and bowsaw are almost unknown in Pakistan. Only a few pieces of these tools belong to the Pakistan Forest Institute, which have been used in this experiment. For the introduction of these tools in timber harvesting work, a regular supply is necessary, which can only be maintained in the initial stages through foreign imports. Federal Republic of Germany and Sweden were once the leading manufacturers of these tools. Change in technology in these countries have diverted the attention of manufacturers to the

production of power tools, but still these hand tools appear in some of the catalogues of forestry equipment supplying firms. Possibilities of import of these tools from other countries like Japan and the Peoples Republic of China can also be explored. India is also manufacturing these tools with the assistance of Sweden, but political relations are a big hinderance for the import of goods from India.

Next and the more dependable alternative for the supply of improved tools is their local manufacture. The technological development of the country is now at such a stage that these tools can very easily be manufactured in the country. There are many engineering firms in the big cities like Lahore and Karachi, which are in a position to make such tools. Proper material if not locally available can be imported from the other countries. Services of design, specifications and control can be provided by the Pakistan Forest Institute Peshawar, through foreign experts.

Basis for the development of piece-rate

Presently the workers which carry out timber harvesting are paid on piece-rate either directly by the forest department or through the agency of forest contractors. The latter system of payments is more common. Payments are said to be on piece-rate because the units of payments correspond to the units of production, but without any firm scientific basis, such as in consideration to individuals performance, terrain, climatic conditions, tree species and work requirements etc. Absence of a good piece-rate is the main cause for the necessity of a forest contractor. The forest contractor do nothing so far as the operational aspect of the work is concerned and only serves as a middle man taking away the maximum share of the workers income. In this study the net profit of the forest contractor has been calculated as more than 130 % (Appendix-III). This method not only makes the timber harvesting operations very expensive for the forest department, but the workers are also deprived of their due right. Even if under the prevailing piece-rate system, the workers are paid

directly by the forest department, the income of forest workers will straight away increase from Rs. 22.42 to Rs. 52.58/man day (135 %) without any extra financial burden on the employer (Appendix-II and III). The present system of piece-rate includes felling and conversion of trees and extraction of timber and firewood with stacking on the compartment road side.

So, for as the use of productivity results of this study as sound scientific basis for the development of piece-rate system in the forest plantations of the Punjab is concerned, some additional studies need to be carried out. Because the labour productivity results in this study are only for tree felling and conversion. A study will be needed for the determination of technical labour productivity in the manual extraction of timber and firewood upto the compartment road side. These results need to be supplemented with follow-up data for providing more reliable basis for a sound piece-rate system. Existence of good piece-rate system will eliminate the necessity of forest contractors, both for the benefit of the worker and employer.

Teaching aid at the Pakistan Forest Institute

The Pakistan Forest Institute is the only research and teaching organization in the country in different disciplines of forestry. Recently the subjects of work science and ergonomics have been introduced in the syllabus of M. Sc. forestry course. The investigation at hand, besides giving the full methodology of conducting research on the work performance and physical workload, also serves as a usefull teaching aid to the forestry student providing informations on the different kinds of forest workers, their method of work, availability and association with the forest administration, ergonomics and socio-economic aspects of forest work along with the possibilities of improvement, productivity and its various kinds, factors and methods of improvement of productivity, workload, definition, mental, emotional and physical workload, methods of their measurements along with merits and

demerits, limits of sustained performance, heat stress in forest work, effect and indices of heat stress, physical work capacity and its importance.

7 ABSTRACT/ZUSAMMENFASSUNG

7.1 ABSTRACT

Efficiency of improved tools (raker-tooth crosscut saw and bow-saw) with the training of workers and conventional tools (axe and peg-tooth cross-cut saw) and methods was compared with respect to time, productivity and physical workload on the workers during tree felling and conversion in the irrigated forest plantation of Changa Manga in Pakistan. The workers worked in the party sizes of 2, 3 and 4 persons with each type of tools.

Observation on time with the help of multimoment time study techniques at an observation interval of 1 minute were recorded. Heart rate observations as a measure of physical workload were made manually with the help of a stop-watch, at carotid artery near Adams apple or radial artery in the wrist of the workers during work at an observation interval of 3 minutes.

In all 351 trees of mulberry and shisham were felled and converted with an average DBH of 27 cm.

Analysis of data showed that the corrected total work time/m³ of tree volume remained as 72.4 and 60.0 minutes with conventional and improved tools, respectively. Improved tools gave a total work time saving of 12.4 minutes/m³ of tree volume or 17 % as compared to conventional tools. Effective time/m³ of tree volume also showed a decrease of 6.7 min or 13.5 % with improved tools.

The work of firewood conversion remained the most time intensive operation with both types of tools, followed by crosscutting, felling and debranching of trees. Results of multiple linear regression analysis between the dependent variables of work times and independent variables of tree parameters, showed that the

tree volume was the strongest determinant of different work times/tree.

Improved tools caused a highly significant increase of 23 % in the technical labour productivity (timber + firewood) with respect to total work time and was 0.249 and 0.307 m³/man hour with conventional and improved tools, respectively. Harvesting cost per m³ of production also remained lower by about 11 % with improved tools in comparison to conventional tools.

For work with conventional tools a work party size of 2 persons showed optimum productivity, while a work party size of 3 persons working with improved tools gave the best performance.

Improved tools also caused a highly significant reduction in the physical workload on the workers as depicted by a lower average total pulse value of 101 pulse beats/min against 110 pulse beats/min for work with conventional tools. The work of tree felling was the most heaviest job with conventional tools, with an average total pulse of the workers as 132 beats/min, while improved tools proved very effective in cutting down the workload in felling with an average working pulse of 108 pulse beats/min in this operation.

Within the different work party sizes, the maximum workload was experienced by a work party of 2 persons, while the work parties of 3 and 4 persons worked at a lower and comparable workload.

A work party size of 3 persons working with improved tools remained optimum, giving the best work performance at comparatively less workload.

Introduction of improved tools and working methods as well as systematic vocational training of forest workers are very essential for increased labour productivity at lower physical workload in timber harvesting in Pakistan.

7.2 ZUSAMMENFASSUNG

In den bewässerten Forstplantagen von Changa Manga, Pakistan, wurden die Auswirkungen herkömmlicher und verbesserter Werkzeuge und Arbeitsverfahren auf Arbeitszeitbedarf, Arbeitsproduktivität und körperliche Beanspruchung bei der Holzernte untersucht. Die herkömmlichen Werkzeuge umfaßten Axt und Handsägen mit Dreiecksbezaehlung, die verbesserten Werkzeuge vor allem Handsägen mit Hobelbezaehlung. Die Waldarbeiter waren in den verbesserten Werkzeugen und Arbeitsverfahren zuvor unterwiesen und trainiert worden. Jede Werkzeugausstattung und jedes Arbeitsverfahren wurde für Rottengrößen von 2, 3 und 4 Mann untersucht.

Bei den Zeitstudien kam das Multimomentverfahren mit einem konstanten Beobachtungsintervall von 1 Minute zur Anwendung. Als Indikator der körperlichen Beanspruchung durch die Arbeit diente die Herzschlagfrequenz. Sie wurde in Intervallen von 3 Minuten an der Halsschlagader oder am Handgelenk manuell gemessen.

Im Rahmen der Untersuchung wurden 351 Mulberry- und Shisham-Bäume mit einem mittleren Bruthöhendurchmesser von 27 cm gefällt und aufgearbeitet.

Unter vergleichbaren Bedingungen betrug der Aufwand an Gesamtarbeitszeit für die herkömmliche Arbeitsweise 72,4, für das verbesserte Verfahren 60,0 min/m³. Letzteres führte somit zu einer Zeiteinsparung von 12,4 min/m³ oder 17 %. Bei der reinen Arbeitszeit ergab das verbesserte Verfahren eine Zeiteinsparung von 6,7 min/m³ oder 13,5 %.

Die Aufbereitung von Brennholz erwies sich bei beiden Arbeitsweisen als der zeitaufwendigste Ablaufabschnitt, gefolgt vom Einschneiden, Fällen und Entasten. Multiple Regressionsanalysen zeigten, daß das Baumvolumen den bei weitem größten Einfluß auf den Zeitbedarf ausübt.

Verbesserte Werkzeuge und Arbeitsverfahren führten zu einem Anstieg der auf die Gesamtarbeitszeit bezogenen technischen Arbeitsproduktivität von 23 % gegenüber der Arbeit mit traditionellen Werkzeugen und Verfahren. Die Holzerntekosten pro m³ lagen bei der verbesserten Arbeitsweise um 11 % unter jenen bei herkömmlichen Werkzeugen und Verfahren.

Gemessen an der technischen Arbeitsproduktivität erwiesen sich bei herkömmlichen Werkzeugen und Arbeitsverfahren die 2-Mann-Rotte, bei verbesserten Werkzeugen und Verfahren die 3-Mann-Rotte als optimal.

Verbesserte Werkzeuge und Arbeitsverfahren ergaben einen hochsignifikanten Rückgang der körperlichen Beanspruchung (im Gesamtdurchschnitt 101 gegenüber 110 Pulsschläge pro Minute). Der Fällvorgang mit traditionellen Werkzeugen war die schwerste Teilarbeit (i.D. 132 Schläge pro Minute); mit verbesserten Werkzeugen konnte die Beanspruchung auf i.D. 108 Schläge pro Minute gesenkt werden.

Die im Durchschnitt höchste körperliche Beanspruchung wurde bei beiden Arbeitsweisen für die 2-Mann-Rotte gemessen. 3- und 4-Mann-Rotte arbeiteten auf deutlich niedrigerem und annähernd gleichem Beanspruchungsniveau. Technische Arbeitsproduktivität und körperliche Beanspruchung in Betracht gezogen, läßt die mit verbesserten Werkzeugen und Arbeitsverfahren arbeitende 3-Mann-Rotte die besten Ergebnisse erwarten.

Die Untersuchung weist eindeutig darauf hin, daß in Pakistan durch die Einführung verbesserter Werkzeuge und Arbeitsverfahren bei der Holzernte sowie durch die planmäßige Berufsausbildung der Waldarbeiter die technische Arbeitsproduktivität erhöht und die körperliche Beanspruchung gesenkt werden könnten.

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COST OF WORK/m³ OF PRODUCTION WITH CONVENTIONAL
TOOLS (Level-I) AND IMPROVED TOOLS (Level-II)

1. Labour Costs

Average daily work duration	= 5.3 hours
Daily wage rate/man day	= Rs. 30.00
Labour cost/man hour	30/5.3 = Rs. 5.66
(No social costs are at the liability of the employer)	

I

2. Costs of Tools

Depreciation period of hand tools	= 3 years
Annual utilization of hand tools	= 1,000 hours
Depreciation period in hours	= 3,000 hours

(i) Cost of Conventional Hand Tools

Type of tool	No.	Approx. Price/ Piece	Total (Rs.)
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Axes (Local)	4	120	= 480.00
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Crosscut Saws peg-tooth (imported)	2	456	= 912.00
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Wedges Iron (Local made)	2	10	20.00
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Total investment in conventional tools	= Rs. 1412.00
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Depreciation of conventional tools per man hour	$\frac{1412}{3000 \times 4} = \text{Rs. } 0.12$
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Interest on the investment in tools (at 10 %)/man hour	$\frac{1412 \times 0.5 \times 10}{100 \times 1000 \times 4} = \text{Rs. } 0.02$
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Maintenance cost of Conventional tools

Monthly pay of mistri	
Professional man for tool maintenance	= Rs. 1200.00

Hourly cost of mistri	$\frac{1200}{30 \times 5.3}$	= Rs. 7.55
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Cost of a triangular file		= Rs. 30.00
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Hourly cost of a file	$\frac{35}{10 \times 5.3}$	= Re. 0.66
(Approximate life of a file is taken as 10 days of use)		

Hourly Cost of Tools Maintenance	= Rs. 8.21
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Approximate time needed for sharpening of a crosscut saw peg-tooth	= 15 min
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Cost of sharpening of 2 crosscut Saws (one sharpening daily) $2 \times 8.21/4 = \text{Re.} 4.12$

Man hour cost of sharpening $4.21/5.3 \times 4 = \text{Re.} 0.19$

Approximate man hour cost of maintenance of 4 axes $= \text{Re.} 0.04$

Total man hour cost of maintenance of conventional tools $0.19 + 0.04 = \text{Re.} 0.23$

Man hour cost of conventional tools:

Depreciation $= \text{Re.} 0.12$

Interest $= \text{Re.} 0.02$

Tool maintenance $= \text{Re.} 0.23$

Total $= \text{Re.} 0.37$

II

(ii) Cost of Improved Tools

Type of Tool	No.	Approx. Price/ Piece Rs.	Total Rs.
Axes (local)	4	120	= 480.00
Raker-tooth Saws (imported)*	2	846	= 1692.00
Bowsaws (imported)*	4	175	= 700.00
Bill-hooks (locally made)	4	60	= 240.00
Wedges Steel Felling (Imported)*	4	120	= 480.00
Wedges Steel C.cut (imported)*	4	40	= 160.00
Wedges Steel Bowsaw (imported)*	4	20	= 80.00
Total investment in Improved Tools			= 3832.00
Depreciation of improved tools 3832/3000x4 per man hour			= 0.32
Interest on the investment in improved tools (10 %) per man hour			$\frac{3832 \times 0.5 \times 10}{100 \times 1000 \times 4} = 0.05$

Maintenance cost of improved tools

Man hour cost of mistri and file =Re.0.23

(Though the time demand for the maintenance of raker-tooth saw is two to three times higher than peg-tooth saw, but raker-tooth needed less frequent maintenance as compared to peg-tooth saw. Therefore, the same man hour cost of mistri and file are used as for peg-tooth)

Cost of 4 bowsaw blades (imported)* 60 X 4 =Rs.240.00

(Four bowsaw blades were consumed in 18 days of work and 14 days of training, all these were with hard tempered teeth)

Man hour cost of 4 bowsaw blades =Re.0.35

Approximate man hour cost of maintenance of 4 axes =Re.0.04

Cost of accessories used in the maintenance of improved tools

Cost of one setting guage (imported)* =Rs.488.00

Cost of raker adjuster (Approx.) =Rs.195.00

Cost of setting tool (Approx.) =Rs. 90.00

Total investment in tools maintenane accessories =Rs.773.00

Useful life of tool maintenance accessories = 5 years

Useful life in hours 1000 X 5 = 5000 hours

Depreciation of accessories/man hour $\frac{773}{5000 \times 4}$ =Re.0.04

Interest on the investment $\frac{773 \times 0.5 \times 10}{100 \times 1000 \times 4}$ =Re.0.01
in accessories(10 %) per man hour

Total man hour cost of maintenance =Re.0.67

Man hour cost of improved tools

Depreciation =0.32

Interest =0.05

Tool manintenance=0.67

Total =Rs.1.04

III

*(The cost of tools with remarks as "imported" are taken from the 1984-85 Catalogue of a West German Tool Supplying Firm M/S. Forstkultur GMBH. The prices in Geramn Mark are changed into Pak. Rupee by multiplying with 5 and then increased by 30% as packing and transport charges. No custom duties are added, because of the tools being used in public sector)

3. Cost of Training in the use of Improved Tools

Duration of Training		= 14 days
Cost of Teachers and Instructors:		
Pakistan Forest Institute(PFI) Staff		
1 Teacher	175 x 14	=Rs.2450.00
1 Technician	75 x 14	=Rs.1050.00
	Total	=Rs.3500.00
(Cost of PFI Staff includes the pay and daily allowances)		
Cost of West German Expert for 7 days	1500 x 7	=Rs.10,500.00
Miscellaneous Teaching Aids		=Rs. 100.00
Cost of improved tools used in training for 14 days		=Rs. 308.67
Total Cost of Training		=Rs.14,408.67
Approximate average working life of a worker		= 30 years
Yearly cost of training	14,408.67/30	=Rs. 480.29
Man hour cost of training	480.29/1000x4/5.3	=Rs. 0.02

IV

4. Cost/man hour of Work

(i) Conventional Tools:

Labour	=Rs.5.66	I
Tools	=Rs.0.37	II
Training	=Rs. Nil	
Total	=Rs.6.03	

(ii) Improved Tools:

Labour	=Rs.5.66	I
Tools	=Rs.1.04	III
Training	=Rs.0.02	IV
Total	=Rs.6.72	

5. Cost/m³

(i) Conventional Tools:

Technical Labour Productivity = 0.249 m³/man hour
with conventional tools

Cost/man hour of conventional tools = Rs.6.03

$$\text{Unit Cost/m}^3 = 6.03/0.249 = \boxed{\text{Rs.24.22}}$$

(ii) Improved Tools:

Technical Labour Productivity = 0.307 m³/man hour
with improved tools

Cost/man hour of improved tools = Rs.6.72

$$\text{Unit Cost/m}^3 = 6.72/0.307 = \boxed{\text{Rs.21.89}}$$

Improved tools are about 11% more economical than conventional tools in felling and conversion of mulberry and shisham trees in Changa Manga Plantation.

LABOUR EARNINGS IN TIMBER HARVESTING

For work on piece-rate for forest contractor.

Work duration

Total timber and firewood produced = 122.62 m³ (solid)
(mulberry+ shisham)

Technical labour productivity = 0.249 m³/man hour

Technical labour productivity/man day = 0.249 x 5.3

= 1.32 m³

Work duration in man days = $\frac{122.62}{1.32}$ = 92.9

Work duration inclusive of extraction = 92.9 x 1.40

of timber and firewood(Approx. = 130.1 man days (I)

Extraction time is taken as 40% of
the total work time)

Earnings

Timber shisham = 88 logs

Rate = Rs.14.00/log

Earnings = 88 x 14 = Rs.1,232 (II)

Billets mulberry+
shisham = 548

Rate = Rs.2.00/billet

Earnings = 548 x 2 = Rs.1,096 (III)

Firewood mulberry + = 74 m³ (stacked)
shisham (factor 0.65)

Rate = Rs. 7.95/m³

Earnings = 74 x 7.95 = Rs.588.30 (IV)

Total Earnings = II + III + IV = Rs.2,916.30

Earnings/man day $2916/130.1$ = Rs.22.42

PROFIT OF THE FOREST CONTRACTOR

Total volume of mulberry timber = 32.37 m³
 Rate = Rs. 70.60/m³
 Payments received = 32.37 x 70.60 = Rs.2,285.32 (I)

Total volume of shisham timber = 42.15 m³
 Rate = Rs.88.25/m³
 Payments received = 42.15 x 88.25 = Rs.3,719.74 (II)

Total firewood volume = 74 m³ (stacked)
 (mulberry + shisham)
 Rate = Rs.11.30/m³
 Payments received = 74 x 11.30 = Rs.836.20 (III)

Total payments received by the contractor

$$= I + II + III$$

$$= \text{Rs.6,841.26}$$

Payments made to the workers = Rs.2,916.30

Net profit of forest contractor = 6,841.26-2,916.30
 = Rs.3,924.96
 = 135 %

Labour earnings if the workers are
 directly paid by the forest department

$$= 6841.26/130.1 = \boxed{\text{Rs. 52.58/man day}}$$

$$\text{Increase in earnings} = \frac{52.58-22.42}{22.42} \times 100$$

$$= \underline{135 \%}$$

TREE VOLUME AND TREE TIMES

Mulberry and shisham with conventional tools

Tree Vol.m ³	Felling min	Hang-up min	Debranch min	Firewood min	Measur. min	Crosscut. min	Effect.T. min	T.Work.T min
0.50	4.7	0.4	2.7	12.5	0.6	8.5	30.0	44.1
1.00	7.9	0.4	4.3	20.7	0.7	14.8	49.5	72.4
1.50	11.0	0.4	5.8	29.0	0.9	21.1	68.9	100.7
2.00	14.2	0.3	7.3	37.2	1.1	27.4	88.3	129.1
2.50	17.4	0.3	8.9	45.5	1.3	33.8	107.7	157.4
3.00	20.6	0.3	10.4	53.8	1.5	40.0	127.1	185.8
3.50	23.7	0.2	11.9	62.0	1.7	46.4	146.6	214.1
4.00	26.9	0.2	13.4	70.2	1.8	52.7	166.0	242.5
4.50	30.1	0.2	15.0	78.5	2.0	59.0	185.4	270.8
5.00	33.3	0.1	16.5	86.8	2.2	65.3	204.8	299.2
5.50	36.4	0.1	18.0	95.0	2.4	71.6	224.3	327.5
6.00	39.6	0.1	19.6	103.2	2.6	77.9	243.7	355.9

Mulberry and shisham with improved tools

0.5	5.1	0.1	1.3	12.3	0.6	5.5	25.3	36.0
1.0	7.6	0.1	2.6	20.4	0.7	10.8	42.8	60.0
1.5	10.2	0.2	3.9	28.5	0.9	16.0	60.2	84.1
2.0	12.7	0.2	5.2	36.5	1.1	21.2	77.6	108.1
2.5	15.3	0.3	6.5	44.6	1.3	26.4	95.1	132.1
3.0	17.8	0.3	7.9	52.7	1.5	31.7	112.5	156.1
3.5	20.3	0.4	9.2	60.8	1.7	36.9	129.9	180.1
4.0	22.9	0.4	10.5	68.9	1.9	42.1	147.3	204.1
4.5	25.4	0.5	11.8	77.0	2.1	47.3	164.8	228.1
5.0	28.0	0.5	13.1	85.1	2.3	52.6	182.2	252.1
5.5	30.5	0.6	14.5	93.2	2.5	57.8	199.6	276.1
6.0	33.1	0.7	15.8	101.3	2.6	63.0	217.1	300.1

Shisham with conventional tools

0.5	3.6	0.5	1.0	9.2	0.5	7.3	22.7	34.3
1.0	6.9	0.5	2.8	17.6	0.7	13.5	42.5	63.2
1.5	10.2	0.4	4.5	26.0	0.8	19.8	62.4	92.2
2.0	13.5	0.4	6.3	34.4	1.0	26.0	82.2	121.1
2.5	16.8	0.3	8.0	42.9	1.2	32.3	102.1	150.0
3.0	20.1	0.3	9.7	51.3	1.4	38.5	121.9	179.0
3.5	23.4	0.2	11.5	59.7	1.5	44.7	141.8	207.9
4.0	26.7	0.2	13.2	68.1	1.7	51.0	161.6	236.8
4.5	30.0	0.1	15.0	76.6	1.9	57.2	181.5	265.8
5.0	33.3	0.1	16.7	85.0	2.0	63.5	201.3	294.7
5.5	36.7	0.04	18.5	93.4	2.2	70.0	221.1	323.6
6.0	40.0	0.01	20.2	101.8	2.4	75.9	241.0	352.6

TREE VOLUME AND TREE TIMES

Shisham with improved tools

Tree Vol.m ³	Felling min	Hang-up min	Debranch min	Firewood min	Measure min	Crosscut. min	Effect.T min	T.Work.T min
0.5	4.9	0.02	0.8	9.1	0.5	5.4	21.3	30.6
1.0	7.5	0.03	2.2	17.4	0.7	10.7	39.3	55.3
1.5	10.1	0.05	3.6	25.8	0.9	16.1	57.2	80.1
2.0	12.7	0.07	5.0	34.2	1.1	21.5	75.2	104.8
2.5	15.3	0.08	6.4	42.5	1.3	26.9	93.1	129.5
3.0	17.9	0.10	7.8	50.9	1.5	32.3	111.1	154.3
3.5	20.5	0.11	9.2	59.3	1.7	37.7	129.0	179.0
4.0	23.1	0.13	10.6	67.6	1.9	43.0	147.0	203.8
4.5	25.7	0.14	12.0	76.0	2.1	48.4	164.9	228.5
5.0	28.3	0.16	13.4	84.4	2.3	53.8	182.9	253.3
5.5	30.8	0.18	14.8	92.7	2.5	59.2	200.8	278.0
6.0	33.4	0.19	16.2	101.1	2.7	64.6	218.8	302.8

Mulberry with conventional tools

0.25	3.2	0.42	2.2	8.0	0.4	4.8	19.6	29.0
0.50	5.1	0.41	3.4	14.8	0.7	9.9	35.0	50.5
0.75	7.1	0.40	4.6	21.7	0.9	15.1	50.4	72.1
1.00	9.0	0.39	5.8	28.5	1.2	20.2	65.8	93.6
1.25	10.9	0.38	7.0	35.3	1.5	25.3	81.2	115.1
1.50	12.9	0.37	8.3	42.1	1.7	30.5	96.6	136.7
1.75	14.8	0.37	9.5	48.9	2.0	35.6	112.0	158.2
2.00	16.8	0.36	10.7	55.8	2.3	40.8	127.3	179.7

Mulberry with improved tools

0.25	3.4	0.9	0.8	8.7	0.5	2.8	16.6	24.1
0.50	5.3	0.9	1.8	16.1	0.7	5.9	30.3	42.3
0.75	7.1	0.9	2.7	23.5	0.8	9.1	44.0	60.6
1.00	9.0	0.8	3.7	30.9	1.0	12.3	57.6	78.8
1.25	10.9	0.8	4.7	38.4	1.2	15.5	71.3	97.0
1.50	12.7	0.8	5.7	45.8	1.3	18.7	85.0	115.3
1.75	14.6	0.8	6.7	53.2	1.5	21.8	98.6	133.5
2.00	16.5	0.7	7.7	60.6	1.7	25.0	112.3	151.7

Bio-data of Mohammad AYAZ

Born	on 7.1.1946 in village Nawanshehr, District Abbottabad as son to Mr. Wali Mohammad
Primary School	1950 - 1954, Govt. Primary School, Nawanshehr
High School	1955 - 1960, Govt. High School, Nawanshehr
Govt. College Abbottabad	1960 - 1964, got a B.Sc. Degree
Botany Dept. University of Peshawar	1964 - 1966, got a M.Sc.Degree in Botany
Pakistan Forest Colleg, Univers. of Peshawar	1977 - 1979, got a M.Sc.Degree in Forestry
Service Record	1967, as Research Assistant at the Pakistan Forest Institute, Peshawar 1972, as Wood Technologist at the Pakistan Forest Institute, Peshawar 1982, as Logging Officer at the Pakistan Forest Institute, Peshawar
Experience	Research and teaching experience in wood structure and properties, timber harvesting, work science, ergonomic and forest utilization Published a number of research publication in the above forestry fields
Married	Since 1970 with Arifa Ayaz, 3 children.

